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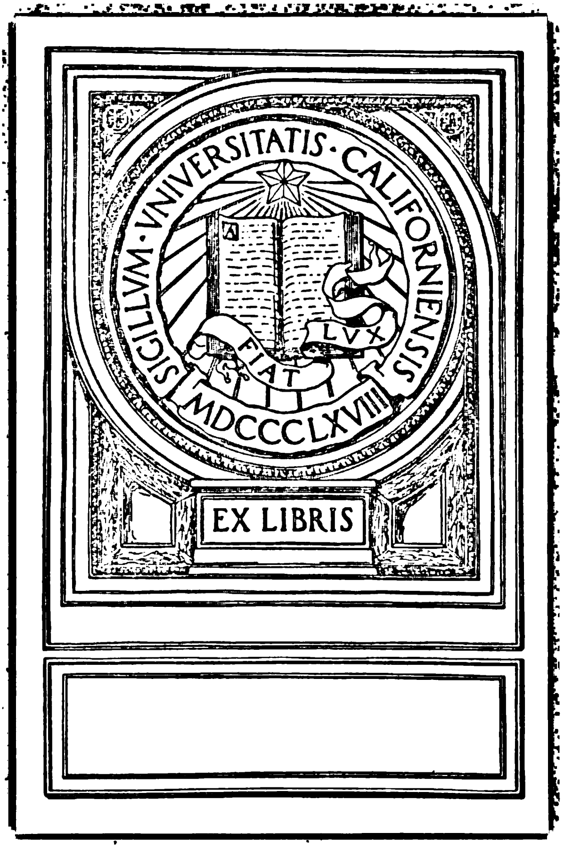
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OREGON COOPERATIVE WORK

DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE
in cooperation with
STATE OF OREGON

DESCHUTES PROJECT

University of California
MAY 24 1943
Documents Division

BY

The cooperating officers of the State of Oregon and the Reclamation Service Office at Portland, Oregon

December, 1914

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DESCHUTES PROJECT

INTRODUCTION.

AUTHORITY.

Authority for Oregon Co-operative work and this report is Act of Congress, June 17th, 1902, (32 Stat., 388), commonly known as The Reclamation Act, and subsequent, supplementary and amendatory acts, on the part of the United States, and an act of the Legislature, Chapter 87, General Laws of Oregon, 1913, on the part of the State of Oregon.

The Reclamation Act is well known and need not be repeated here. The State law authorizing this work is as follows:

AN ACT

To provide for detail surveys and investigations of the water resources of the State of Oregon, making an appropriation therefor, and providing for co-operation with federal agencies engaged in similar work.

Be it enacted by the People of the State of Oregon:

Section 1. In order that the natural resources of the State of Oregon in land, water and power may be utilized to the highest advantage of the people, complete co-operation between the state and federal authorities in controlling, investigating and developing these resources in the interest of the people of the state is essential; therefore, the State Engineer is hereby authorized, on behalf of the State of Oregon, to enter into such contract or agreement with any federal department or bureau having jurisdiction in such matters for the execution of such surveys and investigations and the preparation of such plans, specifications and estimates or other data by co-operation between the state and such federal department or bureau as will, in the judgment of the State Engineer, approved by the Governor, be best suited to accomplish the purposes of this act; provided, that in no case shall the proportion of expense to be borne by the State of Oregon exceed the proportion to be borne by the other party or parties to such contract or agreement.

Section 2. As soon as practicable after the completion of such surveys and investigations, the State Engineer shall prepare or cause to be prepared a report setting forth the plans, specifications and estimated cost of construction, maintenance, and operation of such projects, together with any other information tending to show the feasibility of the same, and may in his discretion have such report printed in pamphlet form and distributed to those interested. Copies of all completed maps, plans, specifications, estimates and reports secured or prepared in connection with any such investigation shall be kept on file in the office of the State Engineer at all times, and shall be open for public inspection during business hours.

Section 3. The State Engineer, on behalf of the state, is hereby authorized and required to withdraw and withhold from appropriation any unappropriated water which may be required for projects under investigation or to be investigated under the provisions of this act. If the project is found to be feasible, he shall withhold the same from appropriation until the money expended in the investigation of such project shall be repaid to the co-operating parties in proportion to the amount contributed by each. No permit to appropriate water which may be in conflict with any such project under investigation shall be approved by the State Engineer, nor shall any assignment of plans and information or any part thereof be made except upon consideration and other (Sic) by the State Water Board after full hearing of all interested parties.

Section 4. As the purposes of this act are to secure the most immediate, as well as the most beneficial, ultimate use of the available waters for any certain project, it is assumed that the State Engineer will, as occasion may require, and he is hereby authorized, to grant permits, and arrange the details so that minor portions of the project may be segregated and constructed at any time; provided, however, that the segregation and development of such minor part or parts, shall not interfere to any serious extent with the handling of or completion of the balance of the project.

Section 5. The intent of this act, as outlined in Section 2, is to have on file ready and available, such detailed surveys and information as will not only permit, but that will tend to induce the beneficial use of water by private persons, irrigation districts, corporations, or possibly by the state or national government.

Section 6. There is hereby appropriated out of any money in the general fund of the state treasury, the sum of $50,000 to carry out the provisions of this act, to be expended on vouchers approved by the State Engineer in the same manner as the salaries of state officials are paid. This appropriation shall constitute a revolving fund in the hands of the State Treasurer for the investigation of other projects as herein provided, and upon any moneys being returned to the State Engineer, they shall be promptly turned over to the State Treasurer and again become a part of this fund.

Section 7. **Whereas**, it is important that this act shall become effective immediately in order that water-right withdrawals may be made upon certain streams to be investigated under this act, and to head off complications and controversies which would otherwise arise, thus endangering the public peace, health and safety; and

Whereas, it is further necessary that provisions be made for beginning such investigations during the early spring in order to have a full working season for field work, therefore, an emergency is declared to exist, and this act shall be in force and effect from and after its approval by the Governor.

Filed in the office of the Secretary of State February 21, 1913.''

AGREEMENTS.

AGREEMENT, MAY 5, 1913

Under authority of these acts an agreement was entered into between the United States and the State of Oregon on February 27, 1913, providing for the manner of carrying on the investigations. This agreement was amended by a subsequent agreement under date of May 5, 1913, to more fully conform to the requirements of the Federal laws.

Following is the agreement under which the work has been conducted:

''**This agreement** made this fifth day of May, 1913, between the **United States of America**, by Franklin K. Lane, Secretary of the Interior, pursuant to the act of June 17, 1902 (32 Stat., 388), and acts amendatory thereof and supplementary thereto, and the **State of Oregon**, by John H. Lewis, State Engineer, subject to the approval of the Governor of the State of Oregon, pursuant to the act of the Oregon legislature (House Bill No. 73), filed in the office of the Secretary of State of Oregon February 21, 1913, **witnesseth**: that—

(1) **Whereas**, an act of the Legislature of the State of Oregon (House Bill No. 73), approved by the Governor February 21, 1913, provides for the making of detail surveys and investigations in co-operation with federal departments or bureaus engaged in similar work, and appropriates fifty thousand dollars ($50,000) to carry out its provisions, and further provides that the amount of money contributed by the State on any investigations made pursuant to said act shall not exceed the amount contributed by the co-operating parties; and

(2) **Whereas**, the Secretary of the Interior has allotted the sum of fifty thousand dollars ($50,000) to be expended on such work in co-operation with the State of Oregon;

(3) **Now, therefore**, in consideration of the premises and the mutual covenants and agreements herein contained, it is stipulated and agreed between the parties hereto as follows:

(4) That surveys and investigations be made in that portion of the State of Oregon known as Central Oregon, and more particularly in the basin of the Deschutes River, in order to ascertain the feasibility of irrigation projects therein, to outline their limits, character, and cost of their development; also to determine the ways and means whereby the public waters, natural lakes, reservoir sites, state and public lands, and other resources may be used, reserved, or disposed of in

connection with such irrigation projects to the highest public advantage; also to determine what power may be developed as an incident to the construction of such irrigation projects and the value and possible uses thereof.

(5) That prior to or during the prosecution of detailed investigations hereunder, the Secretary of the Interior shall take such action as is authorized by law, and in his judgment and discretion may be deemed advisable, to prevent the attachment of rights to the public lands which may interfere with the development of projects proposed for irrigation, and the State Engineer of Oregon shall likewise secure such action as is authorized by law to withdraw and withhold from appropriation any unappropriated water which may be required for the development of any such project.

(6) That all surveys and investigations contemplated hereunder shall follow a general plan of operations jointly agreed upon by the State Engineer of Oregon and the Reclamation Service through its proper officers.

(7) That on completion of the work aforesaid all field notes, original plans, and other data acquired or prepared during said investigations shall be filed with the United States Reclamation Service, but shall be accessable at all times to the State Engineer or his duly authorized representatives upon application, and a copy thereof shall be furnished the State Engineer for official record on request.

(8) That on completion of the work herein contemplated a report shall be promptly made and published, outlining the scope of the investigations made, giving detailed statements and estimates of each project investigated, with suitable explanatory plans, maps and other documents as exhibits, together with a summary of expenses incurred in the investigations, such expenses being segregated and itemized for each project as far as practicable; that such report shall also contain specific conclusions and recommendations as to the future policy considered most advisable to be followed by the United States and the State of Oregon n utilizing, reserving, or disposing of public lands, waters, reservoir and power sites, and other natural utilities in conformity with the plan of development indicated by this investigation as being to the highest public advantage; that these conclusions and recommendations shall be jointly agreed upon by the State Engineer and the officer of the Reclamation Service having jurisdiction, or in the event of their failure to agree thereon each of them shall submit separate conclusions and recommendations, both of which shall be embodied in the report and published; that such advance reports shall be prepared and furnished to the State Engineer and the Reclamation Service as may be required and agreed upon; that in all reports and publications it shall be clearly shown that the United States and the State of Oregon are joint contributors to the work, and the names of co-operating officers shall be stated.

(9) That in carrying out all work hereunder one-half of the expense shall be borne by the State and one-half by the Reclamation Service, the total expense to be incurred by each not to exceed fifty thousand dollars ($50,000); that each month a detailed statement of cost, together with report of work accomplished, shall be made to the Reclamation Service and to the State Engineer, of the total expense for the last preceding month, such expenses including all proper costs chargeable to the field office and administrative work of the investigation. Such statement shall also give the proportion of expense that has been borne by both the Reclamation Service and the State, and from time to time during the progress of the work necessary adjustment shall be made in the expenditures on salaries and other expenses by the Reclamation Service and by the State as will equalize the aggregate expenditure by each party, so that at the conclusion of the work the proportion of the expense borne by each shall be equal.

(10) That all employes engaged in this investigation paid by the Reclamation Service shall be subject to the established rules and regulations of the United States Civil Service Commission governing such employes; that all employes paid by the State shall be subject to such rules and regulations as the State may provide in such cases; **Provided,** that all employes paid by the State shall be subject also to such rules and regulations as the Reclamation Service may establish for the conduct of these investigations, and that in the selection of employes preference will be given to residents of the State, other considerations being equal.

(11) No member of or Delegate to Congress, or Resident Commissioner, after his election or appointment, or either after or before he has qualified and during his continuance in office, shall be admitted to any share or part of this contract or agreement, or to any benefit to arise thereupon. Nothing, however, herein contained shall be construed to extend to any incorporated company, where such contract or agreement is made for the general benefit of such incorporation or com-

pany, as provided in Section 116 of the act of congress approved March 4, 1909, (35 Stat., 1109).

(12) This contract shall take the place of and be substituted for that certain contract on the same subject-matter entered into under date of February 27, 1913, duly executed by Walter L. Fisher, Secretary of the Interior, on behalf of the United States of America, by John H. Lewis, State Engineer of the State of Oregon, on behalf of said State, and approved by Oswald West, Governor of the State of Oregon; **Provided**, that any contracts or obligations entered into by the contracting parties, or either thereof, under and by virtue of said contract for which this contract is a substitute, and not inconsistent with or contrary to the terms of this contract, shall be in all respects valid and binding the same as if entered into after the execution of this contract.

In witness whereof, this instrument has been executed by the parties hereto the day and year first above written.

(Signed) FRANKLIN K. LANE,
Secretary of the Interior, for and on behalf of the United States of America.

(Signed) JOHN H. LEWIS,
State Engineer, for and on behalf of the State of Oregon.

Approved May 5, 1913.
By (Signed) OSWALD WEST,
Governor of the State of Oregon.''

SUPPLEMENTARY AGREEMENT

As required in paragraph 6, of the Agreement of May 5, 1913, a supplementary agreement as to surveys and investigations for the season of 1913 was entered into as follows:

''Memorandum of Agreement reached by the State Engineer of Oregon and officials of the Reclamation Service in the matter of co-operative work by the United States and the State of Oregon in investigations in Central Oregon under agreement between the Secretary of the Interior and the State Engineer of Oregon, dated May 5, 1913:

It has been mutually agreed by the officers subscribing hereto to limit operations under the co-operative contract as follows:

a. To concentrate attention on the large reservoir proposed for construction on the Deschutes River a few miles south of Bend.

b. To make detailed surveys of the dam site a few miles south of Bend.

c. To make diamond drill borings and explorations by test pits, shafts and such other methods as may be desirable in order to determine the feasibility of dam construction at the dam site a few miles south of Bend.

d. To prosecute surveys of such main canal lines as may be necessary to utilize waters conserved in the above reservoir on irrigable lands lying on both sides of the Deschutes River.

e. To make detailed surveys, borings and other investigations at the dam site on the Crooked River (a branch of the Deschutes River).

f. Concurrently with the above work in Deschutes Basin, to make such preliminary examinations in the John Day, Malheur, Silvies, Klamath and other basins in Central Oregon as will determine the advisability of undertaking detailed surveys, similar to those now proposed for the Deschutes Basin.

The gross expenditures estimated in connection with the above work are $30,000.

It is contemplated to hold further conferences as the scope of these investigations requires enlargement or extension from time to time.

Executed at Portland, Oregon, this 8th day of July, 1913.

(Signed) JOHN H. LEWIS,
State Engineer of Oregon.

(Signed) E. G. HOPSON,
Supervising Engineer, U. S. R. S.''

EXTENT OF CO-OPERATIVE WORK CONDUCTED BY THE UNITED STATES AND THE STATE OF OREGON.

For many years numerous state governments have co-operated with the United States in the making of topographic and hydrographic surveys.

During the past nine years the State of Oregon through the State Engineer's Office has co-operated with the United States Geological Survey in the making of topographic surveys and in the conducting of hydrographic work, and quite recently in the making of river surveys to determine the water power possibilities of some of the most important streams of the State. During the past two years the State Bureau of Mines has conducted geologic investigations in conjunction with the United States Geological Survey.

The State through its Agricultural College has co-operated with the United States Department of Agriculture in conducting farm experiments and in measuring the volume of water used in irrigation systems. At the present time, work is being carried on by the War Department, in conjunction with the State of Oregon and the Port of Portland, to improve the navigability of Willamette and Columbia Rivers.

A water power survey of Deschutes River by the United States Geological Survey, W. S. Paper 344, in co-operation with the State of Oregon in 1912, doubtless influenced the State Legislature and the Federal authorities to initiate the present co-operative work, since this survey disclosed reservoir capacity sufficient to store the entire excess run-off of Deschutes River at Benham Falls, over and above that available and now largely appropriated for use during the irrigating season.

ORGANIZATION FOR CONDUCTING SURVEYS AND INVESTIGATIONS.

An engineering force was engaged shortly after the approval of the agreement of February, 1913, between the United States and Oregon, and offices in the Central building at Portland, Oregon, were secured.

Field surveys and office studies on which this report is based have been made by State and Federal engineers, acting under the personal direction of John T. Whistler, with general supervision by E. G. Hopson, pursuant to the general plan specified in the supplementary agreement between State Engineer John H. Lewis and E. G. Hopson, Supervising Engineer, United States Reclamation Service.

This report has been written by John T. Whistler in conference with E. G. Hopson and John H. Lewis, and is subscribed to by these three parties on behalf of the co-operating State and Federal authorities. Attention is, however, directed to the fact that the subscription to this report by these individuals does not commit other officials of the State or Government to the conclusions reached herein.

ployed as field assistants; later F. C. Dillard, formerly of the Reclamation Service in Oregon, was employed as field assistant. All of the above have been in charge of survey parties. Harry Caden, Clerk and Fiscal Agent, of the Reclamation Service, was transferred from the Klamath project as chief clerk and fiscal agent for this work. James Dopson, formerly of the Reclamation Service, has made the necessary diamond drill and other borings at the various dam sites.

A report on the North Canal Unit of the Central Oregon Irrigation Company's Carey Act segregation was prepared by Joseph Jacobs, Consulting Engineer, in conjunction with State Engineer John H. Lewis and Supervising Engineer E. G. Hopson. The North Canal report was issued as an advance section of this report, being designated Bulletin No. 1.

A report upon a proposed extension of the State Tumalo Project, prepared by O. Laurgaard, Project Engineer for the Tumalo Project, was embodied in an advance section of this report, designated as Bulletin No. 2.

C. M. Redfield, Chief Engineer of the Central Oregon Irrigation Co., was also employed in consultation, with special reference to unit costs and irrigation problems in that locality.

The soils survey was made by W. L. Powers, Assistant Professor of rigation and Drainage, Oregon Agricultural College.

DESCHUTES BASIN—GENERAL DESCRIPTION.

ie Deschutes drainage basin and its relation to other drainage s is shown on Sheet No. 115. It extends from Columbia River on rth, with an elevation of a little less than 150 feet above sea o the Walker Range on the southwest at an elevation of over et, and to the Blue Mountains on the southeast at about the ation. East of the Walker Range on the south, the actual ween the Deschutes Basin and the Great Basin of the interuncertain. The boundary line as shown is probably the it of any run-off within recent times.

iver north of Bend, and Crooked River, its largest tribu- Prineville, are in practically continuous canyons, fre- icturesque and interesting. The main Deschutes River ies from the west are, with few exceptions, streams ly little fluctuation between extreme high water and r. The normal minimum discharge of the lower river ,000 second feet. Much of the water is from the d peaks of the Cascade Mountains and the river clear.

Now there are branches of both the Hill and Harriman systems which parallel the lower river and extend to Metolius, from which point a joint line is operated as far south as Bend.

With the exception therefore of the extreme southern and southeastern parts of the basin, transportation facilities, for so comparatively undeveloped a region, are hardly excelled anywhere.

Much grain has been grown in recent years on Agency Plains and in what is known as the Haystack country north of Haystack Butte to Willow Creek. Little or none of this region is more than six or seven miles from the railroads, and markets for produce of these lands will therefore be especially accessible.

Lumber, mining and fishing interests of Oregon and Washington, and the Alaska trade, as at present developed, would, no doubt, continue to offer a good market for all the produce that can be grown in the territory tributary to Columbia River and Puget Sound. The Panama Canal, however, will certainly extend that market, for the reason that these same lumber, mining and fishing interests of the Northwest, will be better able to compete with other sections, and this will in turn, undoubtedly result in an increase in the population and wealth of this territory, upon which the market in question depends.

IRRIGATION PROJECTS IN DESCHUTES BASIN COMPLETED OR UNDER CONSTRUCTION.

On the east side of Deschutes River and south of Crooked River, the Central Oregon Irrigation Company, successors to Deschutes Irrigation and Power Company, have constructed main canals and have generally completed the distribution system for two units of their projects, known as the Central Oregon unit and Pilot Butte unit, respectively. The Central Oregon unit extends over an area of approximately 45,000 acres, and the Pilot Butte unit over approximately 20,000 acres of irrigable land. The diversion for the Central Oregon canal takes out from Deschutes River approximately three miles south of the town of Bend. Until within the past year, the Pilot Butte canal has been served from the Central Oregon canal. It is now being served by the uncompleted North canal which will be referred to subsequently in this report.

The Arnold Ditch diverts from Deschutes River at the head of Lava Island Falls, approximately three miles south of the Central Oregon canal diversion. The area which will ultimately be served by the Arnold Ditch is uncertain. The present area irrigated is said to be possibly 2,500 acres.

The Deschutes Reclamation and Irrigation Co. canal (The Swalley Ditch), originally diverted from Deschutes River about one-half mile below the town of Bend, but now diverts at the north canal dam of the Central Oregon Irrigation Company. The area which this ditch will ultimately serve is also uncertain, but has been estimated to be from 5,000 to 10,000 acres.

At Cline Falls a direct connected pumping plant has been in operation for a number of years, pumping water from Deschutes River to a few hundred acres on the low bench adjoining. Recently this pumping plant has been taken over by an electric power company and operated in conjunction with a plant on Crooked River near its mouth.

The DesChutes Land Company project, sometimes referred to as the Morson Project, proposes to irrigate lands east and south of the town of Lapine, storage for the project being proposed at Crescent Lake. The project is organized through a contract with the state under the Carey Act, and approximately 30,000 acres of public land is covered by the contract.

The State has under construction, the Tumalo Project, covering approximately 22,500 acres. This project was originally initiated under the Carey Act as the Columbia Southern Irrigation Project, and has been known by several different names. The lands to be irrigated lie on the west side of Deschutes River, about the town of Laidlaw. Water is taken from Tumalo Creek, the natural flow of which is insufficient for summer irrigation. Storage is provided in a natural basin originally known as Wimer Flat, supplied by a feed canal diverting water from Tumalo Creek about 3 miles above its mouth.

Squaw Creek irrigation project diverts water from Squaw Creek near the town of Sisters. The area which it will ultimately serve is uncertain.

There are a number of minor irrigation projects along Lower Deschutes River and its tributaries, but as none of them can in any way affect the Deschutes Project herein considered, and as altogether they cover a relatively small area, they will not be referred to here in detail.

OTHER IRRIGATION PROJECTS IN DESCHUTES BASIN—HERETOFORE PROPOSED.

The Oregon Land Corporation has proposed to store water in Odell Lake and Big Marsh within the Deschutes drainage basin, and Fish Lake in the Klamath Basin, to serve a portion of the Central Oregon Military Road Grant, lying on both sides of the divide between the Deschutes and the Klamath drainage basins. The soil of this locality is composed largely of pumiceous sand and it is believed the greater portion of any water so used on the Deschutes side of the divide will ultimately return to the river.

A small project has been developed to use the Paulina Lakes as storage reservoirs. A five-foot dam at the outlet of these lakes appears to control all drainage into the basin.

The Central Oregon Irrigation Company is under contract with the State of Oregon to construct a storage and canal system for what has generally been referred to as the Benham Falls Segregation, lying

Sixth: The development of power during the irrigating period, at Benham Falls, Dillon Falls, and Lava Island Falls immediately below, with accumulated storage water from the Benham Falls reservoir, augmented by the normal seasonal flow, turned into the river and available at these points. The utilization of such power will necessitate the development of industries requiring power during the irrigating season only, such as the pumping of water for irrigation.

Investigations upon Crooked River were not taken up until subsequent to the preparation of this report, for the reason that the stream flow data available at that time did not indicate sufficient unappropriated run-off to irrigate the Haystack and Agency Plains lands. Stream gaugings maintained by the Co-operative Work on Crooked River for the year 1913, however, indicate that the earlier records of discharge were low and that so far as the water supply is concerned, a project to irrigate the Haystack and Agency Plains country from Crooked River in conjunction with lands in vicinity of Prineville, may be feasible, and this feature will therefore be discussed in a subsequent report on Crooked River investigations.

General Conditions Affecting the Project and Miscellaneous Data Available.

GEOLOGY.

A preliminary report on the "Geology and Water Resources of Central Oregon" by Israel C. Russell, United States Geological Survey, 1905, Bulletin No. 252, from a reconnaissance made in the summer of 1903, gives valuable and extremely interesting information in connection with this project. It is practically the only official report of any kind on the geology of this region. Other publications having a bearing on the geology are:

U. S. G. S. Bulletin No. 33, "Notes on Geology of Northern California" by J. S. Diller, 1886. U. S. G. S. Bulletin No. 40, "Changes in River Courses in Washington Territory due to Glaciation," by Bailey Willis, 1887. U. S. G. S. Bulletin No. 108, "A Geological Reconnaissance in Central Washington," by I. C. Russell, 1893. U. S. G. S. Bulletin No. 199, "Geology and Water Resources of the Snake River Plains of Idaho," by I. C. Russell, 1902. Prof. Paper 3, "Geology and Petrography of Crater Lake National Park," by J. S. Diller and H. B. Patton, 1902. Water Supply Paper 78, "Preliminary Report on Artesian Basins in Southwestern Idaho and Southeastern Oregon," by I. C. Russell, 1903. Water Supply Paper 118, "Geology and Water Resources of East Central Washington," by F. C. Calkins, 1905. "Geology of the John Day Basin," by J. C. Merriam, Bulletin, University of California, 1901.

The Deschutes Basin lies within the boundaries of a region which is believed to contain the most extensive lava beds in the world. These beds cover the northern portions of California and Nevada, Central Oregon, Western Washington and Southern Idaho, and the area along the headwaters of the Columbia River into British Columbia.

It is estimated that the area of these lava flows is in the neighborhood of 250,000 square miles and that not less than 150,000 cubic miles of rock have been erupted and spread out on the earth's surface. The flows range in age from the earlier portion of the Tertiary period down to recent time.

For the benefit of those to whom the report by Russell is not available, the following condensed statement of the geology of this region will be of interest:

Quoting from Russell:

"The Valley of the Deschutes, before it was filled so as to produce the broad, generally level surface which is at present its most conspicuous feature, was from 20 to 30 miles wide in the portion west of the Paulina Mountains and Powell Butte, but perhaps had a less width farther north. This large valley, as may be judged from the character of the portions of its bordering slopes now exposed to view, was produced largely by erosion and was at least 800 feet deeper in its central part than the widely extended sheet of basalt forming the surface of the present plain. The material which partly fills the old valley consists largely of water-laid volcanic dust and lapilli, of which sections 700 feet deep are exposed along the lower portion of the canyon of Crooked River and in the adjacent portion of that of Deschutes River. The total depth of this deposit, however, is as yet unknown, as its bottom is not exposed. After the volcanic dust and lapilli, together with minor quantities of sand and clay, was deposited, a sheet of basaltic lava, in general about 80 feet thick, was spread out. Possibly two or more sheets of lava were formed at about the same time which are so similar that their recognition is difficult, and they appear to represent but a single outpouring.

After a lava covering was given to the deep deposit of current-bedded volcanic dust, lapilli, sand, etc., Deschutes River and its tributary, Crooked River, displaced from their former courses, flowed across the plain and excavated canyons, which for many miles near their junction were at least 800 feet deep and in general about a mile wide. The nameless stream which flowed northwest from the Great Sandy Desert (See pg. 76), also cut deeply into the lava plain and its underlying deposits of loose material, and joined the Deschutes about 14 miles south of the locality where Crooked River now comes in. Following the period of erosion, during which not only the main streams of the region, but also their tributaries, cut deep canyons, came another considerable discharge of basaltic lava, which entered the canyons in the region where Deschutes and Crooked rivers now mingle their waters and filled them to a depth of at least 500 feet. Later still, Deschutes and Crooked rivers re-excavated their canyons in the hard, resistant basalt to a depth of over 500 feet, without, so far as known, reaching its bottom. There are thus at least five important episodes in the history of the Deschutes plain that are clearly legible in its present topography."

Glacial action was common over a considerable portion of at least the eastern slopes of the Cascades during the glacial period and there is some evidence that it extends as far east as the town of Sisters in that locality. Suttle and Blue Lakes, northwest of Sisters, Crescent and Odell Lakes at the head waters of West Fork of Deschutes River, and Fish Lake within the Klamath Basin, were clearly formed from glacial moraines deposited at the foot of glaciers. According to Russell, results of glacial action are apparent in the vicinity of Paulina Lakes.

It is certain that at some comparatively recent time in the past, rainfall in this region has far exceeded that of the present. There are numbers of canyons, many of them several hundred feet deep, which now rarely show more than a trickling stream of water, even in the early spring months at the time of melting snows.

The Dry River Bed, shown on Sheet No. 71, is distinctly traceable from its present junction with Crooked River for 50 miles south. It is in places a canyon from 300 to 500 feet deep with almost vertical walls. This drainage depression is now dry, both at and below the surface as shown by the fact that at one point 18 miles southeast of Bend an open well which was put down 100 feet in the gravel bottom encountered no ground water.

Squaw Creek Canyon, from near the town of Sisters to its junction with Deschutes River, is a deep, rugged canyon out of all proportion to the insignificant stream which now occupies it. South of Squaw Creek Canyon is Dry Canyon, almost as large as Squaw Creek Canyon, with no water in it. It seems probable that these deeply eroded canyons were formed during, or immediately subsequent to the glacial period referred to.

Numerous small glaciers still exist in the vicinity of the Three Sisters, Broken Top, Bachelor Peak, Diamond Peak, and Mt. Jefferson. The lava flows are both acid and basaltic, the acid lavas being generally classed by Russell as either andesitic or rhyolitic.

Mingled with the many lava flows are beds of tuff often 50 to 100 feet or more in thickness, formed from volcanic ash and sand thrown out and subsequently solidified or indurated under pressure. Russell describes Powell Butte as "a hard, resistant rhyolitic tuff, with perhaps some quartzite," and says that it is "a remnant of an ancient upland which was deeply eroded before the coming to the surface of the extensive basaltic flows which now form the floor over an extensive portion of the valley of the Deschutes."

Pilot Butte is described as "an ancient volcanic cone composed of basalt, containing conspicuous crystals of hypersthene."

Black Butte is described as very similar to Pilot Butte in its composition. The "summit craigs of compact porphyritic rock are evidently the upper portion of a plug or core of lava that cooled slowly

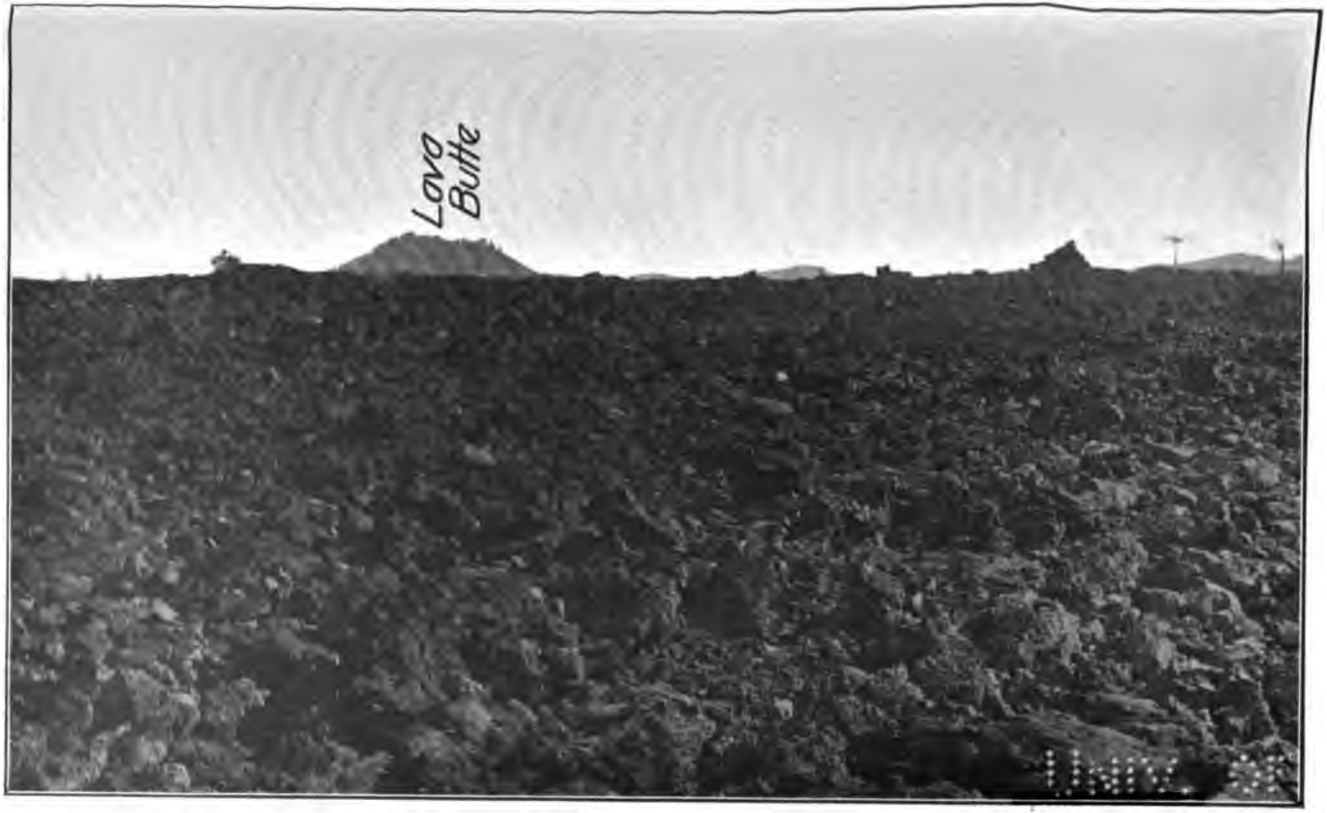

PLATE II.

LAVA BEDS SHOWING LAVA BUTTE IN BACKGROUND.

and hardened in the conduit of the volcanic pile and was subsequently exposed by erosion."

Lava Butte is described as "composed mainly of a coarse angular basaltic lapilli." It contains a crater about 150 feet deep.

The lava beds adjacent were formed by lava which escaped through the base of the Butte on its south side. "The age of this lava flow relative to other volcanic eruptions in the same region is recorded in part by the presence on the country about it, but not on its surface, of pumiceous lapilli or sand which cover the slopes of Mt. Newberry, and the moraines that form the dam across the outlet of its amphitheater."

"Lava Butte and its associated sheet of basalt, like the obsidian lavas in the amphitheater of Mount Newberry, is thus shown to have come into existence since the glacial epoch."

"The presence of pines on Lava Butte, and the occurrence of both living and dead trees on the lava flow that escaped from it, furnish evidence that the activity of the volcano ceased at least a hundred and probably more than a hundred and fifty years ago."

What Russell refers to as double canyons are strikingly visible about the junction of Crooked River with Deschutes River. The history recorded by this evidence is thus described by Russell:

"After the broad, ancient valley of the Deschutes had been filled to a depth in excess of 700 feet with loose stream-deposited debris, consisting mostly of black volcanic sand and gravel, and this material covered by the widely extended sheet of basalt now forming the surface of the major portion of the Deschutes plain, the rivers displaced from their former courses flowed across the young lava plain and excavated canyons in it, which, in the case of Deschutes and Crooked rivers, are a mile wide and over 800 feet deep. Next came a flow of molten basaltic rock, which entered the canyons and filled them to a depth of over 550 feet for many miles. Subsequently the same streams, again displaced but still confined to their former but deeply filled canyons, resumed their work of erosion and cut, in solid basalt, the inner canyon described above. In the portion of the canyon examined the task of cutting through this layer is as yet incomplete and the rivers flow swiftly over solid, compact basalt.

"This is one of the most remarkable instances known of a river struggling, as it were, to maintain its right of way against the opposition offered by stupendous showers or downpourings of volcanic dust and lapilli and by vast outflows of lava which hardened into dense, resistant rock. The time occupied in the excavation of the outer canyons was probably not great, as the material in which these were excavated, with the exception of the covering sheet, was loose and incoherent, but the inner canyons, in places, and for distances in several instances of at least 2 or 3 miles, were cut in hard, compact basalt, and their erosion to a depth of 550 feet must have required many thousands of years."

The irrigable lands on the west side of Deschutes River in the vicinity of the Tumalo Project and as far north as Squaw Creek appear to be somewhat similar to the gravels found in the Deschutes and Crooked River canyons near their junction. It is possible, however, that they are more properly the result of glacial action from the extensive glaciers that must have existed about Three Sisters.

Russell describes the Haystack and Agency Plains country as "an underlying plain covered with a fine, rich soil * * * The soil is fine in texture and evidently owes its origin principally to deposition of wind-blown dust. * * * On the east, the Haystack country is bordered by uplands having a mature topography, such as hills long exposed to the denuding agencies of the air and of rain and streams commonly present. These uplands were a part of the eastern border of Deschutes Valley before it became deeply filled with volcanic dust, sand, gravel, etc., and flooded with lava. Its rocks are composed, so far as known, and judging from topographic forms seen at a distance, probably to a great extent of compact tuffs, in beds which dip westward and pass beneath the Deschutes plains. The hills when seen in profile from the south, present long slopes on the western sides and steep, rocky escarpments facing east."

The sheet of pumiceous sand, or "lapilli," as Russell describes it, which is found over such a large part of this region, extends over an area of about 14,000 square miles. The depth varies from place to place. It generally has been classified as andesite. About Crater Lake the deposit, as described by J. S. Diller, is principally dacite with less degrees of andesite.

Russell himself says that his observations indicate that the sheet of pumice is tolerably uniform in character and composed principally of andesite. The source of this pumiceous sheet is uncertain.

Russell says:

> "As to the location of the volcano from which the pumice was blown into the air and widely distributed, for the most part only tentative suggestion can at present be offered. In part it came from the recent volcanoes, five in number, situated in the old erosion amphitheater of Mount Newberry. This conclusion is based on the fact that the crater rims of these volcanoes are largely composed of andesitic pumice, and large fragments of the same nature are abundant all about the region where they occur. This was probably not the only center of dispersion, however, as the fragments of pumice are still larger and more abundant in the region draining to the Klamath marshes, and, as stated by Diller, were supplied at least in part by eruptions in the great depression now occupied by Crater Lake.
>
> In reference to the date of the explosive volcanic eruptions that supplied such vast quantities of pumice, the fact that this material forms a large percentage of the glacial moraines on Mount Newberry, the Three Sisters peaks, and about Odell and Crescent lakes, shows that the eruption occurred previous to or during the glacial epoch. The moraines about Mount Newberry, and near the lakes just mentioned, are covered with pumice, showing that at least in part, the

eruptions which furnished it were of later date than the glaciers which deposited the moraines. This last conclusion is sustained, also, by the fact that the recent lapilli craters in the old erosion amphitheater of Mount Newberry and the lava flows given out by them are clearly subsequent to the time when that depression was filled with glacial ice. According to Diller, the eruptions of pumice about Crater Lake occurred during and after the time the region about it was occupied by glaciers.''

CLIMATE.

The following records of temperature and precipitation in the Upper Deschutes Basin, for 1913, are from the United States Weather Bureau records, supplemented by data furnished by the Oregon Agricultural College.

CLIMATOLOGICAL DATA FOR 1913

January.

Stations.			Temperature in degrees Fahrenheit.							Precipitation in inches.					Sky.		
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q
Agency Plains..	2,362	2- 2	30.9	28.4	47	2	9	22	....	0.84	1.63	......	......	....	....	....	....
Bend	3,629	3- 2	32.9	30.8	.....	....	....	....	....	......	2.95	......	......	....	....	....	....
Crescent	4,400	3- 6	27.8	23.5	58	31	27	5	56	3.42	4.19	0.86	48.5	18	11	12	8
Culver	2,650	0- 1	......	......	.....	....	....	....	....	......	3.11	......	......	....	....	....	....
Laidlaw	3,171	2- 1	32.8	30.8	59	2	1	5	....	1.00	1.00	......	......	....	....	....	....
La Pine	4,230	1- 2	17.4	17.4	52	31	-26	6	....	......	4.59	......	......	....	....	....	....
Metolius	2,525	3- 3	34.2	31.1	56	26	0	5	30	0.79	1.72	0.79	0	1	24	5	2
Peninsula	2,640	1- 1	38.5	......	.....	....	....	....	....	......	2.18	......	......	....	....	....	....
Powell Butte....	3,240	1- 1	36.6	......	.....	....	....	....	....	......	1.56	......	......	....	....	....	....
Prineville	2.864	17-17	33.2	......	.....	....	....	....	....	......	0.91	......	......	....	....	....	....
Redmond	2,990	2- 1	34.8	37.3	59	27	14	5	21	0.69	0.69	0.30	5.5	6	11	16	4

February.

Stations.			Temperature in degrees Fahrenheit.							Precipitation in inches.					Sky.		
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q
Agency Plains..	2 362	2- 2	30.8	28.8	54	16	9	22	....	0.36	0.45	......	......	....	....	....	....
Bend	3,629	3- 2	34.1	31.4	.....	....	....	....	....	......	1.22	......	......	....	....	....	....
Crescent	4,400	3- 6	30.2	27.1	59	11*	-17	22	57	0.29	2.02	0.17	5.0	6	9	8	11
Culver	2,650	0- 1	......	......	.....	....	....	....	....	......	0.91	......	......	....	....	....	....
Laidlaw	3 171	2- 1	32.4	31.4	62	15	2	22	....	0.35	0.35	......	......	....	....	....	....
La Pine	4,230	1- 2	26.6	26.6	55	15	-13	22	....	......	3.50	......	......	....	....	....	....
Metolius	2,525	3- 3	36.1	32.3	65	15	9	22	35	0.38	0.67	0.25	3.5	2	11	4	13
Peninsula	2,640	1- 1	36.4	......	.....	....	....	....	....	......	0.62	......	......	....	....	....	....
Powell Butte....	3 240	1- 1	33.1	31.4	63	15	4	22	....	0.32	0.23	......	......	....	....	....	....
Prineville	2,864	17-17	36.1	......	.....	....	....	....	....	......	1.03	......	......	....	....	....	....
Redmond	2 990	2- 1	37.1	37.6	62	15*	11	6	34	0.39	0.39	0.25	3.5	4	9	11	8

a. Elevation.
b. Length of period, years, temp. and precip.
c. Mean for the period.

d. Mean for month.
e. Highest.
f. Date.
g. Lowest.
h. Date.

i. Greatest daily range.
j. Total for month.
k. Mean precipitation for period.
l. Greatest in 24 hours.
m. Total snowfall unmelted.

n. Number rainy days, 0.01 in. precip.
o. Number of clear days.
p. Number of partly cloudy days.
q. Number of cloudy days.
r. Prevailing wind direction.

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*Also on other dates.

CLIMATOLOGICAL DATA FOR 1913

May.

Stations.			Temperature in degrees Fahrenheit.							Precipitation in inches.					Sky.			Wind.
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r
Agency Plains..	2,362	1- 1	49.8	49.8	82	31	21	1	37	1.45	1.45	0.48	0	7	18	4	9	nw
Bend	3,629	3- 2	51.1	......	.....	....	....	....	....	......	1.75	......	......	....	....	....	....	......
Crescent	4,400	2- 7	46.0	46.6	85	31	14	1	55	1.23	1.47	0.35	T	8	15	12	3	sw
Culver	2,650	1- 1	54.0	54.0	.....	....	....	....	....	1.71	1.71	......	......	....	....	....	....	......
Laidlaw	3,171	2- 1	52.05	51.6	84	31	21	1	44	1.24	1.24	0.44	0	8	14	8	9	nw
La Pine.......:.	4,230	1- 3	48.4	48.4	85	26	15	1	49	1.34	1.67	0.28	0	10	20	6	5	s
Metolius	2,525	3- 3	52.2	53.2	83	23	20	2	44	1.35	1.33	0.50	0	5	23	2	6	sw
Peninsula	2,640	1- 1	54.8	54.8	87	31	24	1	41	1.47	1.47	0.56	0	6	21	9	1	w
Powell Butte....	3,240	2- 2	51.3	51.9	87	31	21	2	48	1.06	0.75	0.40	0	7	11	10	10	w
Prineville.......	2,864	17-17	53.2	......	.....	....	....	....	....	......	0.92	.....	......	....	....	....	....	......
Redmond	2,990	2- 0	53.8	......	.....	....	....	....	....	......	......	.....	......	....	....	....	....	......

June.

Stations.			Temperature in degrees Fahrenheit.							Precipitation in inches.					Sky.			Wind.
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r
Agency Plains..	2.363	1- 1	54.0	54.0	85	1	35	6	40	0.93	0.93	0.23	0	0	7	15	10	nw
Bend	3,629	3- 2	57.3	......	.....	....	....	....	....	......	0.95	......	......	....	....	....	....	......
Crescent	4,400	2- 7	52.2	51.5	86	1	26	11	55	4.77	1.43	1.31	0	12	18	3	9	sw
Culver	2,650	1- 1	51.5	60.3	93	1*	37	10*	48	1.24	1.24	0.33	0	6	18	0	12	sw
Laidlaw	3,171	2- 1	56.7	57.7	88	1*	33	4	45	2.44	2.44	0.80	0	10	10	9	11	nw
La Pine........	4,230	1- 3	54.0	54.0	88	3	27	11	53	3.36	2.31	1.55	0	21	8	0	22	sw
Metolius	2,525	3- 3	58.7	59.8	92	1	35	10	46	1.27	0.89	0 32	0	7	21	7	2	sw
Peninsula	2,640	1- 1	62.0	62.0	92	2	40	5	40	1.11	1.11	0.32	0	9	12	14	4	w
Powell Butte...	3.240	2- 2	57.8	57.4	89	1	32	5*	49	2.93	1.84	0.70	1.5	10	5	12	13	w
Prineville	2,864	17-18	58.2	......	.....	....	....	....	....	1.29	0.80	0.65	0	0	....	....	....	......
Redmond	2,990	2- 2	61.8	......	.....	....	....	....	....	2.01	1.61	......	......	....	....	....	....	......

a. Elevation.
b. Length of period, years, temp. and precip.
c. Mean for the period.
d. Mean for month.
e. Highest.
f. Date.
g. Lowest.
h. Date.
i. Greatest daily range.
j. Total for month.
k. Mean precipitation for period.
l. Greatest in 24 hours.
m. Total snowfall unmelted.
n. Number rainy days, 0.01 in. precip. or more.
o. Number of clear days.
p. Number of partly cloudy days.
q. Number of cloudy days.
r. Prevailing wind direction.

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*Also on other dates.

CLIMATOLOGICAL DATA FOR 1913

July.

Stations.	a	b	Temperature in degrees Fahrenheit. c	d	e	f	g	h	i	Precipitation in inches. j	k	l	m	n	*Sky.* o	p	q	Wind. r
Agency Plains..	2,363	2- 2	60.0	59.8	88	20*	35	2	39	0.26	0.65	0.22	0	2	22	5	4	nw
Bend	3,629	5- 4	64.9	64.4	94	8*	31	12	51	0.55	0.50	0.24	0	4	21	8	2	s
Crescent	4,400	2- 8	57.1	57.6	91	18	25	2*	57	0.93	0.64	0.43	0	6	20	8	3	sw
Culver	2,650	1- 1	57.9	67.9	98	23	34	2	58	0.50	0.50	0.27	0	3	23	6	2	sw
Laidlaw	3,171	2- 1	65.6	65.2	94	8	34	13	58	2.01	2.01	1.63	0	5	24	3	4	sw
La Pine........	4,230	1- 3	58.8	58.8	90	8*	27	2	57	1.50	0.78	0.93	0	4	27	2	2	sw
Metolius	2,525	3- 3	67.1	67.0	98	22*	38	3*	50	0.15	0.30	0.15	0	1	28	3	0	sw
Peninsula	2,640	1- 1	67.8	67.4	97	20	40	15	47	0.58	0.58	0.38	0	2	22	8	0	w
Powell Butte....	3,240	2- 2	64.9	67.3	94	20*	31	13	51	0.67	0.34	0.50	0	3	20	7	4	w
Prineville	2,864	18-18	65.0	64.4	98	31	33	2*	57	0.37	0.34	0.15	0	2	24	1	6	w
Redmond	2,900	2- 2	64.2	......	93	20	....	....	....	0.36	0.25	0.18	0	3	24	7	0	nw

August.

Stations.	a	b	Temperature in degrees Fahrenheit. c	d	e	f	g	h	i	Precipitation in inches. j	k	l	m	n	Sky. o	p	q	Wind. r
Agency Plains..	2.363	2- 2	61.2	61.4	87	22	35	15*	37	T	T	T	0	0	25	4	2	nw
Bend	3,629	4- 4	63.8	65.0	96	22	29	14*	52	0.24	0.42	0.21	0	2	20	11	0	s
Crescent	4,400	3- 8	57.9	59.4	95	24	23	18	65	0.12	0.27	0.05	0	4	18	12	1	sw
Culver	2,650	1- 1	68.0	68.0	100	1	34	15*	51	0.12	0.12	0.12	0	1	23	7	1	sw
Laidlaw	3,171	2- 1	65.1	66.0	93	3*	30	14	50	0.09	0.09	0.05	0	2	24	5	2	nw
La Pine........	4,230	1- 3	59.7	59.7	96	24	23	19	66	0.11	0.53	0.08	0	2	26	1	4	nw
Metolius	2,525	3- 3	65.3	68.4	100	22	35	18	52	0.00	0.27	0.00	0	0	30	1	0	sw
Peninsula	2,640	1- 1	67.8	70.5	97	1	38	15	44	0.10	0.18	0.10	0	1	29	2	0	n
Powell Butte....	3,240	2- 2	64.9	64.7	96	1	31	15	51	1.00	0.50	0.40	0	3	16	9	6	w
Prineville	2,864	18-18	65.0	......	101	1	....	....	....	1.23	0.28	0.40	0	5	20	6	5	w
Redmond	2,990	3- 2	64.2	60.8	90	30	32	18	42	0.11	0.23	0.09	0	2	15	14	2	nw

a. Elevation.
b. Length of period, years, temp. and precip.
c. Mean for the period.

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*Also on other dates.

d. Mean for month.
e. Highest.
f. Date.
g. Lowest.
h. Date.

i. Greatest daily range.
j. Total for month.
k. Mean precipitation for period.
l. Greatest in 24 hours.
m. Total snowfall unmelted.

n. Number rainy days. 0.01 in. precip. or more.
o. Number of clear days.
p. Number of partly cloudy days.
q. Number of cloudy days.
r. Prevailing wind direction.

CLIMATOLOGICAL DATA FOR 1913

September.

Stations.	a	b	Temperature in degrees Fahrenheit.							Precipitation in inches.					Sky.		
			c	d	e	f	g	h	i	j	k	l	m	n	o	p	q
Agency Plains	2,363	1- 1	52.8	52.8	82	12	28	23	38	0.19	0.19	0.19	0	1	22	2	6
Bend	3,629	5- 4	55.5	53.8	90	12	21	24	56	0.15	0.98	0.10	0	2	23	4	3
Crescent	4,400	3- 7	48.6	51.2	90	20	13	25	66	0.34	0.96	0.25	0	3	19	3	8
Culver	2,650	1- 1	57.4	57.4	95	17	25	21*	53	0.17	0.17	0.17	0	2	28	1	1
Laidlaw	3,171	2- 1	55.5	85.4	89	17	24	9*	48	T	T	T	0	0	26	4	0
La Pine	4,230	1- 3	50.9	50.9	90	17*	15	25	66	0.29	1.47	0.14	0	4	23	3	4
Metolius	2,525	3- 3	55.1	58.1	93	17	21	24	53	0.17	0.84	0.17	0	1	20	....	...
Peninsula	2,640	1- 1	59.7	59.7	90	12	32	23*	47	0.14	0.14	0.06	0	3	24	4	1
Powell Butte	3,240	1- 1	57.2	57.2	93	15	24	9*	61	0.18	0.18	0.10	0	2	23	5	2
Prineville	2,864	18-18	56.7	56.0	94	12	22	24	59	0.40	0.65	0.40	0	1	21	6	3
Redmond	2,990	3- 2	52.3	52.6	80	12*	25	23	40	0.29	0.81	0.12	0	3	19	7	4

October.

Stations.	a	b	Temperature in degrees Fahrenheit.							Precipitation in inches.					Sky.		
			c	d	e	f	g	h	i	j	k	l	m	n	o	p	q
Agency Plains	2,363	1- 1	41.3	41.3	65	11*	22	25	31	0.49	0.49	0.25	0	2	17	0	14
Bend	3,629	2- 2	47.9	45.0	78	23	10	4	48	0.24	0.52	0.20	0	3	21	5	5
Crescent	4,400	2- 1	39.8	42.1	80	23	9	25	61	0.35	1.14	0.35	T	1	15	3	8
Culver	2,658	0- 0	......	......	......	....	....	....	....	......	......	......	......	....	....	....	...
Laidlaw	3,171	1- 1	48.6	48.6	80	11	20	4*	50	0.77	0.77	0.30	0	3	20	7	4
La Pine	4,230	1- 3	42.0	42.0	77	2	13	29	49	1.91	1.35	0.80	0	5	18	7	6
Metolius	2,525	2- 2	44.1	47.0	84	23	18	25*	50	0.21	0.21	0.11	0	2	18	4	9
Peninsula	2,640	1- 1	48.9	48.9	78	22	27	24	38	0.24	0.24	0.12	0	3	21	7	3
Powell Butte	3,240	1- 1	50.0	50.0	90	2	21	3*	65	0.15	0.15	0.10	0	2	20	8	3
Prineville	2,864	18-18	49.1	46.2	80	2*	20	25*	49	0.95	0.64	0.30	0	5	19	3	9
Redmond	2,990	3- 2	44.5	43.4	69	1	20	25	39	0.64	0.45	0.21	0	5	16	10	5

a. Elevation.
b. Length of period, years, temp. and precip.
c. Mean for the period.

---

*Also on other dates.

d. Mean for month.
e. Highest.
f. Date.
g. Lowest.
h. Date.

i. Greatest daily range.
j. Total for month.
k. Mean precipitation for period.
l. Greatest in 24 hours.
m. Total snowfall unmelted.

n. Number rainy days, 0.01 in. pre
o. Number of clear days.
p. Number of partly cloudy days.
q. Number of cloudy days.
r. Prevailing wind direction.

From these records it will be noted that in the region south of Cline Falls and Crooked River there is a minimum temperature of 32° or lower during every month in the year. The records do not show the departures from the mean minimum temperatures for each month, but it is a well recognized fact that frosts are to be expected in this region during each month of the year. It is generally claimed that such frosts are not serious and that the resulting damage is slight. It is apparently true that in the arid regions the effect of a slight frost is not so serious as in the more humid regions. It also is probably true, as claimed, that cultivation of the soil tends to raise the minimum temperatures during the growing season. Nevertheless, killing frosts must be expected as late as the month of June and as early as the forepart of September, while there will be occasional frosts during the months of July and August.

It appears from the records that the precipitation at Laidlaw and Powell Buttes during the growing season, is more than twice the mean of the other stations in the Upper Deschutes Basin, Bend being the next in amount, with the other stations gradually decreasing toward the north until at Agency Plains, the precipitation during the growing season, totalling little more than an inch, is but a quarter of that for Laidlaw and Powell Buttes. The mean difference may not actually be so large, though it is common knowledge that the region south of Laidlaw and Powell Buttes has much more precipitation than to the north, at the former place because nearer the mountains and at the latter probably in part because of the buttes themselves.

WATER RESOURCES—SURFACE.

The flow of Deschutes River is one of the most uniform of all the streams in the United States, not only from month to month, but also from year to year. The normal minimum flow during the irrigating season is between 1,500 and 1,600 second feet at Bend. The extreme minimum is usually in mid-winter, when it occasionally drops, for a few days only, to from 1,100 to 1,200 second feet. The minimum discharge of 1,000 second feet, for the period since 1905, occurred on January 4, 1912, while the maximum discharge for the same period was 4,760 second feet and occurred in the latter part of November, 1909.

The following tabulation of maximum, minimum and mean discharge at Benham Falls, together with total run-off in acre-feet, for seasonal years 1904-5 to 1913-14, inclusive, is from the Deschutes power report, Water Supply Paper 344, issued by the United States Geological Survey and State of Oregon in 1914, and subsequent cooperative records:

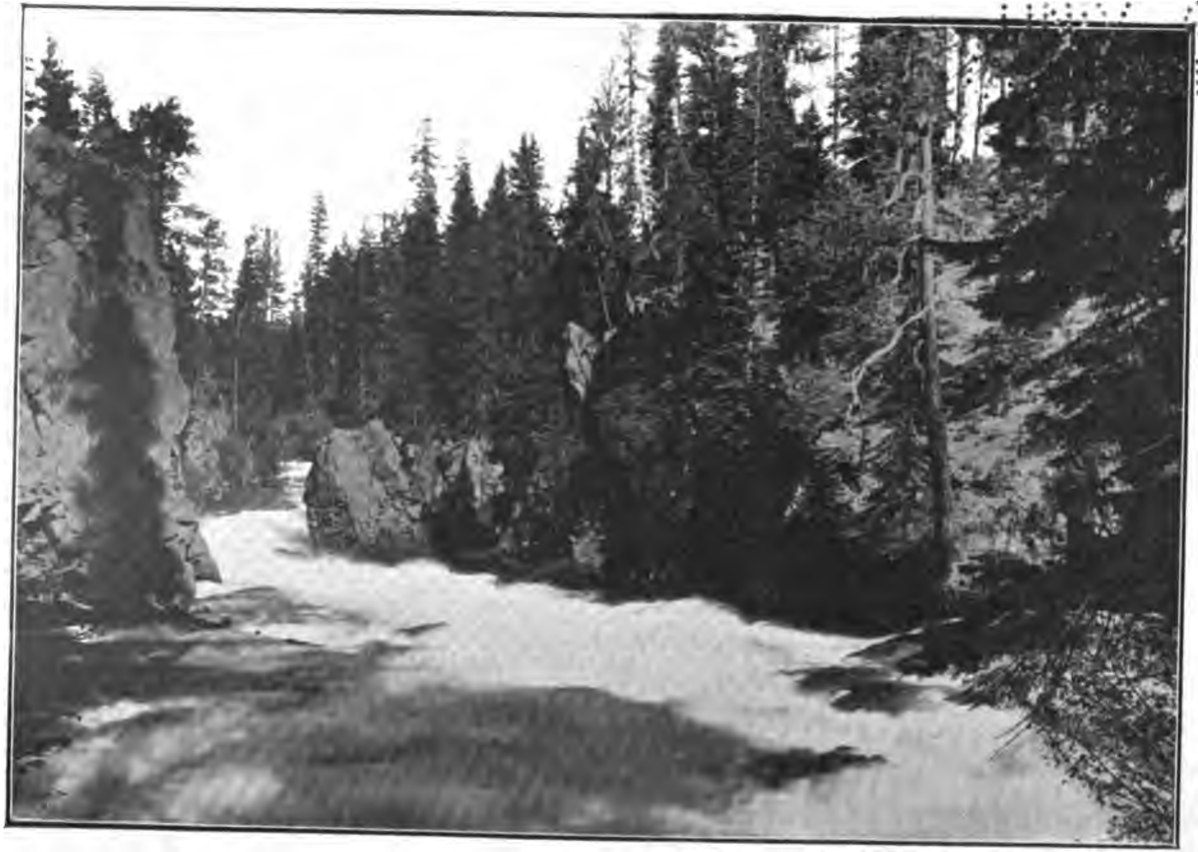

Plate III.

Benham Falls looking Downstream from Midway Point.

ANNUAL DISCHARGE OF DESCHUTES RIVER AT BENHAM FALLS.

Year.	Discharge in second feet— Maximum.	Minimum.	Mean.	Annual Run-off *Acre ft.
1904-5	2,700	1,490	1,950	†1,410,000
1905-6	1,920	1,080	1,520	1,100,000
1906-7	4,000	1,160	1,840	1,340,000
1907-8	2,500	1,280	1,740	1,260,000
1908-9	2,280	1,170	1,620	1,170,000
1909-10	4,760	1,330	1,750	1,270,000
1910-11	1,780	1,180	1,490	1,080,000
1911-12	2,260	1,000	1,590	1,160,000
1912-13	2,130	1,300	1,670	1,210,000
1913-14	1,900	1,250	1,520	1,100,000
Mean for the period—				
1904-14	4,760	1,000	1,670	1,210,000

The largest variation in annual run-off from the mean of ten years is —11.0% for the year 1910-11, and +16.5% for the year 1904-5.

The regularity of flow of Deschutes River is due to two causes, the first and principal one being the unique conditions of underground storage in the drainage area, and the other being the large surface storage of water in the great snow fields and glaciers of the Cascade Range.

In both cases a large portion of the heavy winter and spring precipitation is temporarily withheld from the river, being gradually released from storage during a period extending over the season of the year when, under other conditions, surface stream-flow would be very much reduced or have entirely ceased.

The drainage area of the Deschutes possesses remarkable characteristics, as noted in the chapter on geology, these, however, being very similar to those of the basins of Pit River, (the main feeder of Sacramento River) and Klamath River. The Deschutes, the Klamath and the Pit all drain different slopes of the vast volcanic formation, constituting a large portion of the area within Southern and Central Oregon and Northern California. The Pit carries drainage from the southern and southeastern slopes, the Klamath drains the central and eastern section of the area, and the Deschutes the northerly slopes.

Large portions of this territory are honeycombed and cavernous in structure, these conditions varying in different localities and at different depths. Taking the district as a whole, however, it is clear that vast subterranean storage exists, readily accessible to the seasonal influx from precipitation and equally capable of yielding up its surplus waters. The discharge of these waters is strikingly illustrated by the great springs at the sources of Fall River and Tule River, the main feeders of Pit River in California, where the aggregate discharge of the underground flow that emerges within a radius of a few miles

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[*] The flow of one "cubic foot per second" and designated as "second foot" will, during a period of twenty-four hours, amount to very nearly 2 acre feet.

[†] Mean for October-December, 1904, estimated 2,000 second feet.

GAUGING STATIONS IN UPPER DESCHUTES RIVER BASIN

No.		Records Available.
20.	Arnold Canal near Bend	April 11, 1904—Sept. 30, 1914.
21.	Central Oregon Canal near Bend	Mar. 11, 1905—Sept. 30, 1914.
22.	Pilot Butte Canal near Bend	Mar. 6, 1905—Sept. 30, 1914.
23.	North Canal at Bend	June 14, 1913—Sept. 30, 1914.
24.	Swalley Canal at Bend	July 5, 1913—Sept. 30, 1914
25.	Wimer Canal near Laidlaw	June 16, 1906—Sept. 30, 1914.
26.	Columbia Southern Canal in Laidlaw	May 15, 1906—May 23, 1914.
27.	Tumalo Feed Canal near Bend	May 21, 1914—Sept. 30, 1914.
28.	Metolius River at Allingham Ranger Station, near Sisters	Sept. 15, 1910—Oct. 31, 1913.
29.	Metolius River at Hubbard's Ranch, near Grandview	April 24, 1910—Dec. 31, 1913.
30.	Metolius River at Riggs' Ranch, near Sisters	Oct. 22, 1908—Oct. 21, 1912.
31.	Lake Creek, near Sisters	Mar. 31, 1911—Oct. 31, 1913. (Fragmentary.)
32.	Whitewater Creek, near Grandview	June 2, 1911—Dec. 31, 1913.
33.	Crooked River, near Post	Nov. 9, 1908—Aug. 31, 1911.
34.	Crooked River at Hoffman's Ranch, near Prineville	Jan. 24, 1913—Sept. 30, 1914.
35.	Crooked River at Stearn's Ranch	Nov. 3, 1908—Dec. 31, 1912.
36.	Crooked River at Prineville	Jan. 11, ...—April 17, 1914.
37.	Ochoco Creek at Elliott's Ranch, near Prineville	Nov. 4, 1908—April 30, 1910.
38.	Ochoco Creek at Prineville	May 14, ...—July 13, 1912, and Dec. 15, 1913, to June 20, 1914.
39.	Squaw Creek, near Sisters	July 15, 1906—Dec. 31, 1913.

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Accuracy.

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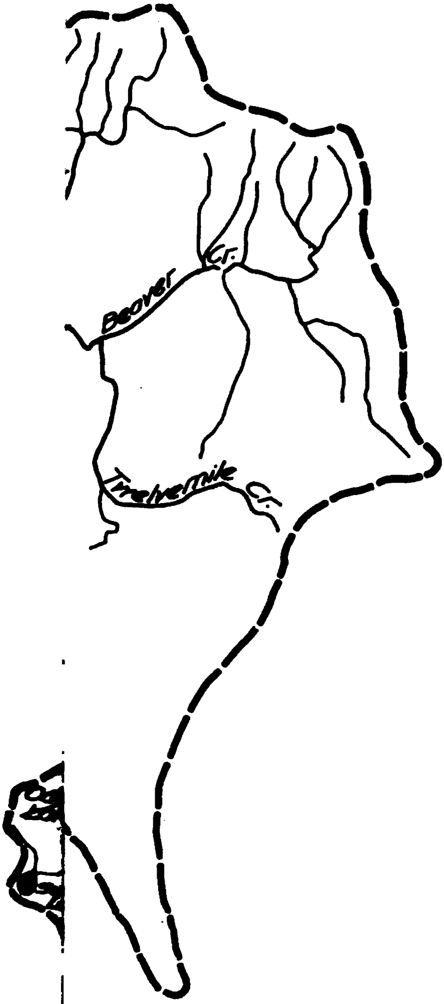


SHEET NO. 1 6 5

No.
20. A
21. C
22. P
23. N
24. S
25. W
26. C
27. T
28. M

29. M

30. M
31. L

32. V
33. C
34. C

35. C
36. C
37. C

38. C

39. S

MONTHLY DISCHARGE OF DESCHUTES RIVER AT BENHAM FALLS, NEAR BEND, OREGON, FOR 1904-1914

Month.	Discharge in second feet.			Run-off (total in acre feet.)	Accuracy.
	Max.	Min.	Mean.		
1904-5—					
October to December	....	....	....	360,000	D
January	2,700	2,080	2,240	138,000	A
February	2,380	1,920	2,160	120,000	A
March	2,260	2,080	2,160	133,000	A
April	2,260	1,920	2,070	123,000	B
May	2,220	1,880	2,010	124,000	B
June	1,890	1,730	1,810	108,000	A
July	1,750	1,630	1,710	105,000	A
August	1,740	1,490	1,620	99,600	A
September	1,640	1,590	1,620	96,400	A
The year	....	....	....	1,410,000	
1905-6—					
October	1,660	1,530	1,620	99,600	A
November	1,620	1,470	1,560	92,800	B
December	1,370	1,080	1,290	79,300	A
January	1,450	1,200	1,360	83,600	A
February	1,410	1,240	1,330	73,900	A
March	1,550	1,250	1,360	83,600	A
April	1,880	1,530	1,710	102.000	B
May	1,920	1,700	1,840	113,000	B
June	1,920	1,650	1,770	105,000	B
July	1,680	1,430	1,560	95,900	B
August	1,430	1,360	1,410	86,700	A
September	1,400	1,360	1,370	81,500	A
The year	1,920	1,080	1,520	1,100,000	
1906-7—					
October	1,360	1,290	1,320	81,200	A
November	1,510	1,290	1,370	81,500	A
December	1,510	1,320	1,390	85,500	A
January	1,610	1,160	1,390	85,500	B
February	4,000	1,520	2,300	128,000	B
March	2,060	1,610	1,750	108,000	B
April	2,500	1,680	2,170	129,000	B
May	2,680	2,430	2,510	154,000	B
June	2,540	2,120	2,350	140,000	B
July	2,120	1,900	2,020	124,000	B
August	1,900	1,800	1,860	114,000	B
September	1,850	1,700	1,770	105,000	B
The year	4,000	1,160	1,850	1,340,000	

MONTHLY DISCHARGE OF DESCHUTES RIVER AT BENHAM FALLS, NEAR BEND, OREGON, FOR 1904-1914

Month.	Discharge in second feet.			Run-off (total in acre feet.)	Accuracy.
	Max.	Min.	Mean.		
1907-8—					
October	1,700	1,590	1,630	100,000	B
November	1,700	1,520	1,580	94,000	B
December	2,560	1,480	1,770	109,000	B
January	2,060	1,390	1,700	105,000	B
February	1,520	1,280	1,440	82,800	B
March	1,960	1,350	1,600	98,400	B
April	2,230	1,560	1,880	112,000	B
May	2,120	1,850	2,030	125,000	B
June	2,180	1,850	2,000	119,000	B
July	2,010	1,750	1,890	116,000	B
August	1,750	1,660	1,680	103,000	B
September	1,660	1,560	1,620	96,400	B
The year	2,560	1,280	1,740	1,260,000	
1908-9—					
October	1,900	1,560	1,660	102,000	B
November	1,700	1,520	1,570	93,400	B
December	1,520	1,170	1,430	87,900	B
January	2,280	1,280	1,650	101,000	B
February	1,750	1,520	1,620	90,000	B
March	1,750	1,520	1,570	96,500	A
April	1,800	1,590	1,720	102,000	A
May	1,870	1,690	1,790	110,000	A
June	1,870	1,690	1,790	107,000	A
July	1,690	1,530	1,600	98,400	A
August	1,560	1,510	1,530	94,100	A
September	1,560	1,500	1,520	90,400	A
The year	2,280	1,170	1,620	1,170,000	
1909-10—					
October	1,530	1,430	1,480	91,000	A
November	4,760	1,400	2,040	121,000	B
December	2,610	1,530	1,930	119,000	B
January	1,740	1,330	1,530	94,100	A
February	1,880	1,420	1,590	88,300	A
March	2,380	1,950	2,090	129,000	A
April	2,020	1,880	1,950	116,000	A
May	2,090	1,840	1,980	122,000	A
June	1,840	1,670	1,750	104,000	A
July	1,670	1,570	1,610	99,000	A
August	1,570	1,510	1,540	94,700	A
September	1,510	1,480	1,500	89,300	A
The year	4,760	1,330	1,750	1,270,000	

MONTHLY DISCHARGE OF DESCHUTES RIVER AT BENHAM FALLS, NEAR BEND, OREGON, FOR 1904-1914

Month.	Discharge in second feet.			Run-off (total in acre feet.)	Accuracy.
	Max.	Min.	Mean.		
1910-11—					
October	1,540	1,420	1,470	90,400	A
November	1,600	1,420	1,490	88,700	A
December	1,780	1,420	1,560	95,900	A
January	1,540	1,180	1,420	87,300	A
February	1,420	1,240	1,360	75,500	B
March	1,540	1,240	1,400	86,100	A
April	1,670	1,480	1,570	93,400	A
May	1,740	1,600	1,670	103,000	A
June	1,740	1,600	1,710	102,000	A
July	1,600	1,420	1,500	92,200	A
August	1,420	1,360	1,380	84,800	B
September	1,480	1,360	1,390	82,700	B
The year	1,780	1,180	1,490	1,080,000	
1911-12—					
October	1,420	1,300	1,360	83,600	B
November	1,480	1,300	1,380	82,100	B
December	1,360	1,180	1,280	78,700	B
January	1,500	1,000	1,380	84,800	B
February	1,780	1,430	1,560	89,700	A
March	1,500	1,360	1,430	87,900	A
April	1,710	1,430	1,590	94,600	A
May	2,100	1,710	1,890	116,000	A
June	2,260	1,980	2,150	128,000	A
July	1,940	1,710	1,800	111,000	A
August	1,780	1,640	1,690	104,000	A
September	1,710	1,640	1,670	99,400	A
The year	2,260	1,000	1,600	1,160,000	
1912-13—					
October	1,640	1,570	1,590	97,800	A
November	1,780	1,500	1,620	96,400	A
December	1,570	1,360	1,500	92,200	A
January	1,710	1,300	1,620	93,500	B
February	1,500	1,430	1,440	80,000	B
March	1,640	1,360	1,470	90,400	B
April	1,940	1,640	1,830	109,000	B
May	1,970	1,860	1,910	117,000	B
June	2,050	1,890	2,000	119,000	A
July	2,130	1,680	1,820	112,000	A
August	1,680	1,610	1,670	103,000	A
September	1,680	1,610	1,610	96,600	A
The year	2,130	1,300	1,670	1,206,900	

MONTHLY DISCHARGE OF DESCHUTES RIVER AT BENHAM FALLS, NEAR BEND, OREGON, FOR 1904-1914

Month.	Discharge in second feet.			Run-off (total in acre feet.)	Accuracy.
	Max.	Min.	Mean.		
1913-14—					
October	1,640	1,530	1,570	96,500	B
November	....	....	*1,580	*94,000	C
December	....	....	1,450	89,200	B
January	....	....	1,530	94,100	B
February	....	....	1,450	80,500	B
March	1,830	....	1,640	101,000	B
April	1,900	1,500	1,730	103,000	B
May	1,780	1,610	1,690	104,000	B
June	1,680	1,480	1,570	93,400	B
July	1,500	1,280	1,380	84,800	B
August	1,360	1,250	1,310	80,600	B
September	1,470	1,310	1,360	80,900	B
The year	1,900	1,250	1,520	1,102,000	

* Estimated from tributary stations above.

CRANE PRAIRIE RUN-OFF

The monthly run-off in acre-feet from Crane Prairie, May 1st, 1913, to September 30, 1914, partly estimated, was as follows:

1913.		1914.	
May	22,000	January	17,500
June	26,500	February	13,800
July	26,000	March	16,700
August	26,000	April	19,200
September	27,900	May	22,300
October	22,500	June	20,800
November	19,400	July	19,900
December	18,750	August	20,500
		September	19,600

Year, May, 1913, to April, 1914, incl., 256,250 acre-feet.
“ Oct., 1913, to Sept., 1914 “ 230,950 “ “

IRRIGABLE LANDS AND AVAILABLE SURVEYS

Considerable detailed information of the region was available from records at the State Engineer's office, of the Central Oregon Irrigation Company's surveys for the territory east of Deschutes River to Powell Buttes, and south of Crooked River to the Central Oregon Canal of the Central Oregon Irrigation Company.

Earlier surveys of the present State Tumalo Project had been made but the present very complete topographic surveys of this project were not available at the time when the Deschutes project investigations were begun.

Certain preliminary work had been done by the Central Oregon Irrigation Company or its predecessors in investigations of a project for the so-called Benham Falls Tract of 60,000 acres to 75,000 acres, extending south and southwest of Powell Buttes to about the Dry

River Bed. This consisted of a transit and level line from above Lava Island Falls east to Powell Buttes.

A line of precise levels had been carried through from Klamath Falls to Shaniko some years previously and the bench marks with corrected elevation above mean sea level were available for reference.

The maps of Deschutes River power survey to which reference has been made were also available and the bench marks in the canyon were of value for leveling work.

Further than this there was little information of value and there was practically no data available for the irrigable lands north of Crooked River, generally understood to amount to between 100,000 to 150,000 acres, or west of Deschutes River and north of Cline Buttes, variously estimated at from 30,000 to 75,000 acres.

SURVEYS AND DATA RELATING TO RESERVOIR SITES IN DESCHUTES BASIN

Crescent Lake has for many years been considered one of the most attractive reservoir sites in the Deschutes Basin. The run-off from this lake during the non-irrigating season and available for storage, is but approximately 30,000 acre-feet and, in the event that the project which the DesChutes Land Company has contracted to build near Lapine, under the Carey Act, be completed as proposed, the storage supply from this source will be sufficient for that project only. See United States Geological Survey Water Supply Paper 344 and subsequent data being published.

Davis Lake has been formed by a superficial flow of very porous lava that has damned the stream. The surplus waters escape through the interstices and fissures in the lava and issue in large springs below the barrier. No surface outflow from the lake exists.

It is possible this underflow could be stopped or checked to an extent that would insure control of storage by depositing soil and earth on the upstream face of the lava dike by hydraulic or other process. It is, however, clear that such control would be at best uncertain in its effect and relatively costly in execution, and as other and more desirable storage can be developed elsewhere, no consideration to development of storage at this point, has been given.

Odell Lake drains through Davis Lake and the control of the discharge of water from this lake through the natural channel is subject to the same conditions as Davis Lake. The run-off from Odell Lake during the non-irrigating season and available for irrigation is approximately 45,000 acre-feet. See United States Geological Survey Water Supply Paper 344 and subsequent data being published. It is possible to divert water from Odell Lake around Davis Lake. However, the cost of such canal would make the cost of Odell Lake storage excessive.

Big Marsh, in Township 25 South, Ranges 6 and 7 East, is a depression similar to Odell and Crescent lakes, except that its outlet has cut down so far through the terminal moraine at its mouth that much of it is in general what the name implies, a marsh; but a large part of it is wild hay meadow and grazing land. The run-off available for storage at Big Marsh, approximately 38,000 acre-feet, see United States Geological Survey Water Supply Paper 344, and subsequent data being published, is less than at Odell Lake, but exceeds that at Crescent Lake. The cost of lands for reservoir at this site, because of their use as wild hay meadows and pasture, would make the cost of storage relatively high.

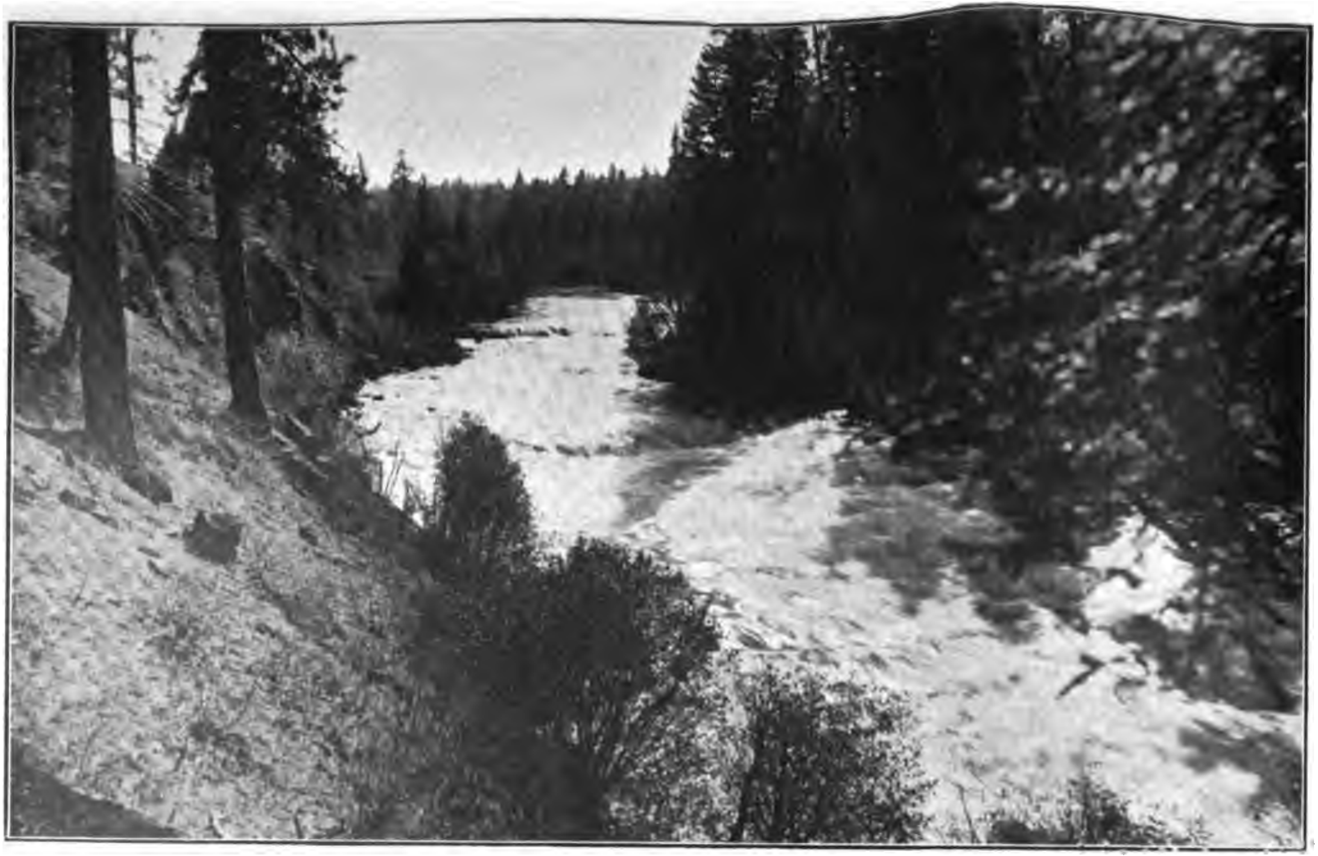
Paulina Lakes. There are no records of the run-off available for storage at these lakes, which are crater lakes, but it is extremely small. Paulina Creek being dry in the summer, and the distance to the main Deschutes River is so great that the seepage losses would be disproportionately large for any diversion of such water at points on the main river below Benham Falls.

Crane Prairie. A reconnaissance survey of Crane Prairie reservoir site was available from the preliminary work of the Central Oregon Irrigation Company. The survey consisted of a single transit line around the site, together with some shallow test pits dug at the site selected for the dam. Storage volumes estimated from the data of this survey, together with estimates of probable run-off of the Deschutes at this point, indicated that the cost of storage at this site would be low. Fissured and scoriaceous lava rock along the north side of the reservoir site and extending from the dam site about two miles along the margin of the prairie may possibly require additional expenditure to prevent excessive losses by seepage. Run-off available for storage is given under "Water Resources."

Benham Falls. This reservoir site, as previously noted, was disclosed by the power survey of Deschutes River made by the United States Geological Survey in co-operation with the State in 1911. Records of flow, see "Water Resources," indicate that the full utilization of the waters of upper Deschutes River, for irrigation only, would require the storage of at least 600,000 acre-feet. Reservoir capacity to this amount can be provided at Benham Falls by raising the water from the present mean river elevation of 4,146 feet, to about 4,208 feet, or approximately 62 feet.

Wimer Flat, a basin north of Tumalo Creek, has been utilized for the storage of Tumalo Creek waters for the State Tumalo Project now under construction. The possibility of diverting water from Deschutes River into this basin, instead of from Tumalo Creek, was investigated by Mr. O. Laurgaard, Project Engineer of the State Tumalo Project, and found to be not so economical as the diversion from Tumalo Creek, because of longer canal line and heavier construction.

Suttle and Blue Lakes. The utilization of water stored in Suttle and Blue lakes has been referred to in this report. See "Other Irri-



Head of Benham Falls.

Plate IV.

UNIV. OF
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gation Projects." It is physically possible to use the run-off from these lakes to irrigate a part of the lands considered in this report, but such use is not considered practicable on account of extreme length of canal line required and character of construction necessary.

Crooked River Reservoir Sites. A reservoir site on Crooked River at the junction of the North and South Forks, near Post, and another site at Ochoco Creek, a tributary of Crooked River, have been the subjects of earlier reconnaissance surveys by the Reclamation Service. Investigations, the results of which will be embodied in a separate report, are now being made of Crooked River Basin and will include surveys of these reservoir sites.

No other reservoir sites upon Deschutes River or its tributaries which will store water to irrigate the lands herein considered, are known to exist.

INVESTIGATIONS FOR THIS REPORT.

FIELD WORK.

Under "General scope and extent of this investigation," it has been pointed out that the irrigable areas under a comprehensive Deschutes Project consist of a North Unit, north of Crooked River and east of Deschutes River; a South Unit, south of the Central Oregon Canal and Powell Buttes; a West Side Unit, north of the present State Tumalo Project and extending north indefinitely on the west side of Deschutes River to possibly as far as Metolius River, and an East Side Unit now generally under contract for development by the Central Oregon Irrigation Company under the Carey Act.

As no surveys whatever were available for the North Unit and the West Side Unit, and but very few for the South Unit on which plans and estimates of much value could be based, it was considered inadvisable to make any detailed topographic survey covering the entire areas. Ordinarily investigations of this character are carried on by successive and alternative preliminary transit lines, run out to eliminate the areas impracticable to irrigate, before any topography surveys of the irrigable lands themselves are made. These surveys require much time, and it was concluded to develop the several features by running out canal lines for each unit at the highest practical elevation and fill in the intervening topography as cheaply as possible to determine approximately the irrigable areas which the canals would need to serve, and the necessary types and costs of the main distributaries.

The main canal lines on which the larger part of the expense of construction would fall were carried out by plane table traverse lines, tying in with section corners for horizontal control and running from known elevations to known elevations in order to check the elevation of intervening points.

Topography was developed along these lines extending on both sides, to either a difference in elevation of not less than 50 feet, or a strip of land not less than one-half mile wide. On this topography 5-foot contour intervals were used. Maps were made on a scale of one-half inch to the mile.

A rough classification of all of the lands under consideration was made by cruising along each section line, and to, or through the center of each section, noting the character of each 40-acre tract in specially prepared land classification books; at the same time rough topography of the area was sketched with the use of a hand level and aneroid barometer, using a contour interval of 25 feet. The value of the results obtained with aneroid barometers in such work is questionable. However, with the exception of the area north of Squaw Creek in the West Side Unit, the work was carried from known elevations to known elevations during each day, so that any errors from the irregularity of the barometer during the intervening time could be distributed between known points; it is believed that the results are sufficiently accurate for the purposes of this investigation.

Cruised topography thus based on aneroid and hand level work is shown on maps in broken lines while plane table topography along canal location is shown in solid lines. See Sheets Nos. 26 to 37, inclusive.

The topography of the Crane Prairie reservoir site was developed by a plane-table survey and the map was plotted on a scale of 1,000 feet to one inch. See Sheet No. 118.

Topography of the several diversion sites, considered together with storage reservoir dam sites at Benham Falls and Crane Prairie, was developed by plane table surveys and the maps plotted on a scale of 400 feet to an inch. See Sheets No. 42, 25, 23, 21 and 67. Test borings were made at the sites of the several diversions and storage reservoir dams. See Sheets No. 42, 67 and 66.

During the season of 1913 the field work consisted in making the surveys of the North Unit, the West Side Unit and the South Unit, together with the surveys of diversion dam sites at Lava Island Falls, and above Laidlaw, and of the dam sites at Benham Falls for the Benham Falls reservoir; test borings were made at the Benham Falls dam sites.

During the season of 1914 the field work consisted in making the survey of the proposed diversion sites at Aubrey Falls and surveys of the Crane Prairie reservoir and dam site, together with test borings at these dam sites. The field work during the season of 1913 was divided into surveys, on the North Side Unit, on the West Side Unit, and on the South Unit, with a field party to each unit, the North Unit, under the charge of Thos. Hawthorne, Assistant Engineer, United

States Reclamation Service, the West Side Unit under the charge of W. R. Parkhill, Surveyman, and the South Unit under the charge of James McKittrick, Surveyman. Mr. F. C. Dillard, of Oregon, for a number of years in the United States Reclamation Service, and especially experienced in the cruising and classification of irrigable land, was placed in charge of this work covering the three units.

The field work during the season of 1914 was under the charge of W. R. Parkhill.

Test borings during both the seasons of 1913 and 1914 were in charge of Mr. James Dopson.

The survey parties consisted of an engineer in charge who acted as topographer, one or two rodmen, a teamster who also acted as rodman, and a cook. The camp equipment consisted of three 12x14 tents, a light cooking range with the usual cooking utensils, and table service of white enameled ware. One medium team with light bolster spring wagon was used both for hauling camp supplies, moving camp and driving to and from the field when working at a distance from camp.

The drill equipment consisted of one diamond drill, hand operated, and one Calyx shot drill, power driven. Each drill was directly in charge of a drill runner, the diamond drill requiring five additional men, and the shot drill one additional man during actual drilling. In addition to the men on the drills, one cook was employed and a teamster with team.

SURVEYS FOR THE WEST SIDE UNIT

It was understood on taking up this investigation, that a large part of the area extending north from Squaw Creek to Metolius River, and west from Deschutes River to Squaw Ridge, and known as the Low Desert, was tillable land and would be productive if irrigated. It was expected also that a considerable body of tillable land would be found along Squaw Creek immediately east of the town of Sisters.

For this unit, a point about one mile above the town of Laidlaw appeared to be the most suitable site for a low diversion, and detailed topography for this site was developed on a scale of 400 feet to the inch. See Sheet No. 25. A canal line, on an assumed fall of one foot to the mile, was run from this diversion point through the pass west of Cline Buttes to the town of Sisters, and thence northerly to the south extension of Squaw Ridge. From this point it was run around the end of Squaw Ridge and north along its easterly slope, to a point about three miles south of Big Canyon and within six miles of Metolius River. See Sheets No. 29, 31 and 32.

During the progress of the survey, it was found that not more than 10,000 acres of land upon the Low Desert would be served and that there was comparatively little irrigable land immediately east of

Sisters that was not already supplied, or to be supplied, with water from Squaw Creek. Furthermore, the line as run out, encountered a half-mile of rim rock about two miles below Laidlaw, through which canal construction would be very expensive.

In considering the diversion above Laidlaw, it was planned to divert the water necessary for a North Unit, in addition to that for any West Side Unit, and carry the supply for both these units in the same canal to a narrow place in the river, approximately four miles north of Laidlaw, where water for the North Side Unit would be taken across Deschutes River by an inverted siphon or a flume. For the North Side Unit, considered by itself, a diversion at some point between this proposed crossing of the river and Aubrey Falls, was at least as economical as the plan to divert water above Laidlaw and across the river below.

When, therefore, it developed that it was impracticable to irrigate land on the Low Desert, and at best not attractive to serve land in the vicinity of Sisters with water from Deschutes River, the plan to divert from a point about 3,500 feet above Aubrey Falls with a dam raising the water approximately 60 feet, was considered for both the West Side and North Units. The canal for the West Side Unit is to take out on the west side of the river, while that for the North Unit is to take out on the east side.

Topography of this diversion site, hereafter in this report referred to as the Aubrey Falls Diversion, was developed, together with an alternative diversion about two miles up stream near Swalley Bridge. See Sheet No. 42.

The canal line from the Aubrey Falls diversion was in great part projected from topography developed by the State for the State Tumalo Project. This topography, which is shown on Sheets No. 31, 32 and 33, was furnished to this investigation by the State Desert Land Board through its Project Engineer.

The topography of the lands investigated for the West Side Unit is shown on Sheets No. 29, 31, 32 and 33.

Diamond drill borings were made at locations shown on Sheet No. 42. Following are records of these borings:

Test Borings, Aubrey Falls Diversion Site.

Hole 1. Surface elevation, 3,101 feet.

Depth in feet.
0 - 4 —Fine gravel, with boulders and disintegrated tuff.
4 - 9 —Light porous disintegrated tuff, with boulders.
9 -17 —Boulders, with gravel and light porous tuff.
17 -20 —Light porous tuff.
20 -25 —Light porous tuff, becoming more solid. Water returned 9 to 25.
25 —Seam, lost water.
25 -29 —Light porous tuff, becoming more solid.
29 —Bottom of hole.

July 20 to July 23, 1914.

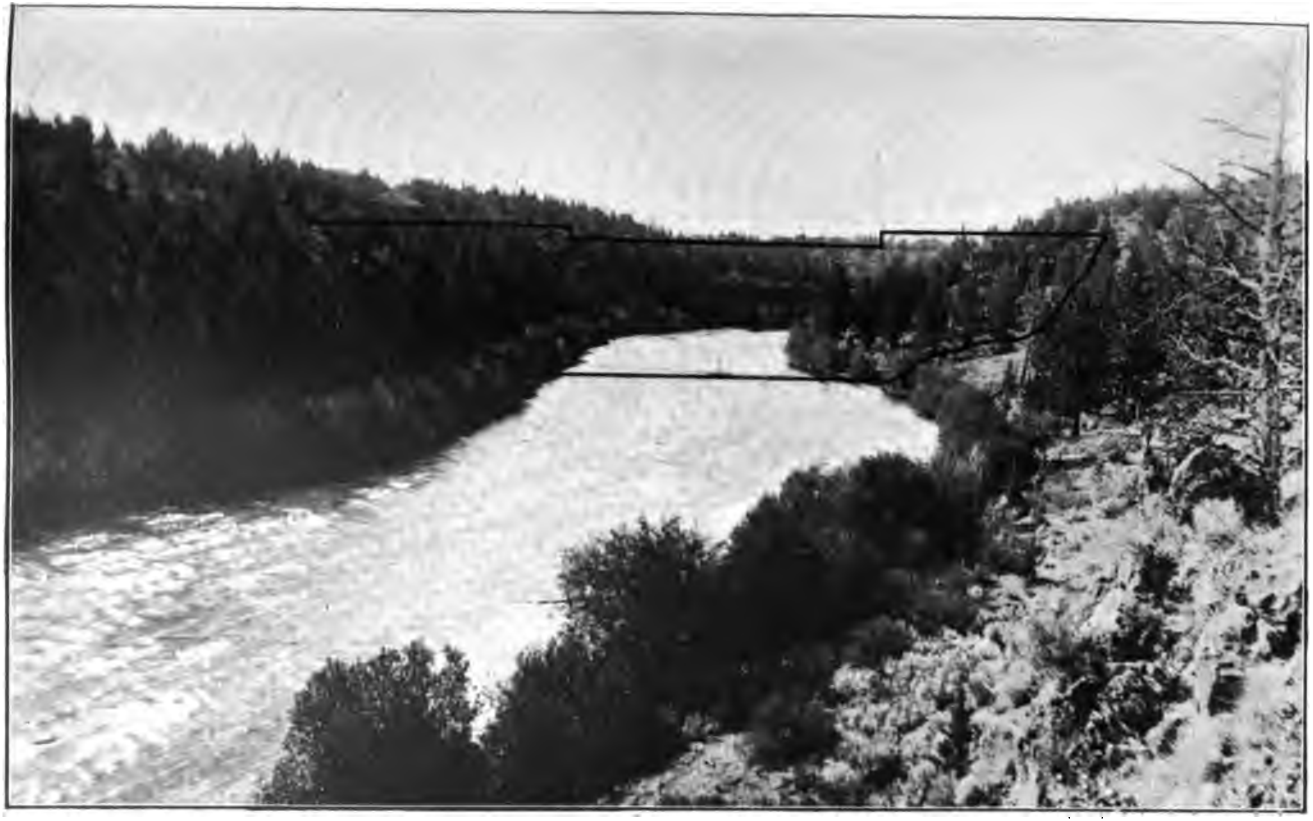


PLATE V.

AUBREY FALLS DIVERSION DAM SITE, SHOWING CRIB FOR CENTER DRILL HOLE.

Hole 2. Surface elevation, 3,135.2 feet.

Depth in feet.
0 - 7 —Very fine sand, with boulders.
7 -18 —Coarse sand or river wash gravel.
18 -29 —Same as above, packed.
29 -33 —Tuff.
33 -35 —Shattered and fissured tuff.
35 -37 —Compact tuff.
37 -38½—Basalt.
38½-43 —Porous red lava.
43 -43½—Basalt.
43½—Bottom of hole.

Hole 3. Surface elevation, 3,131.7 feet.

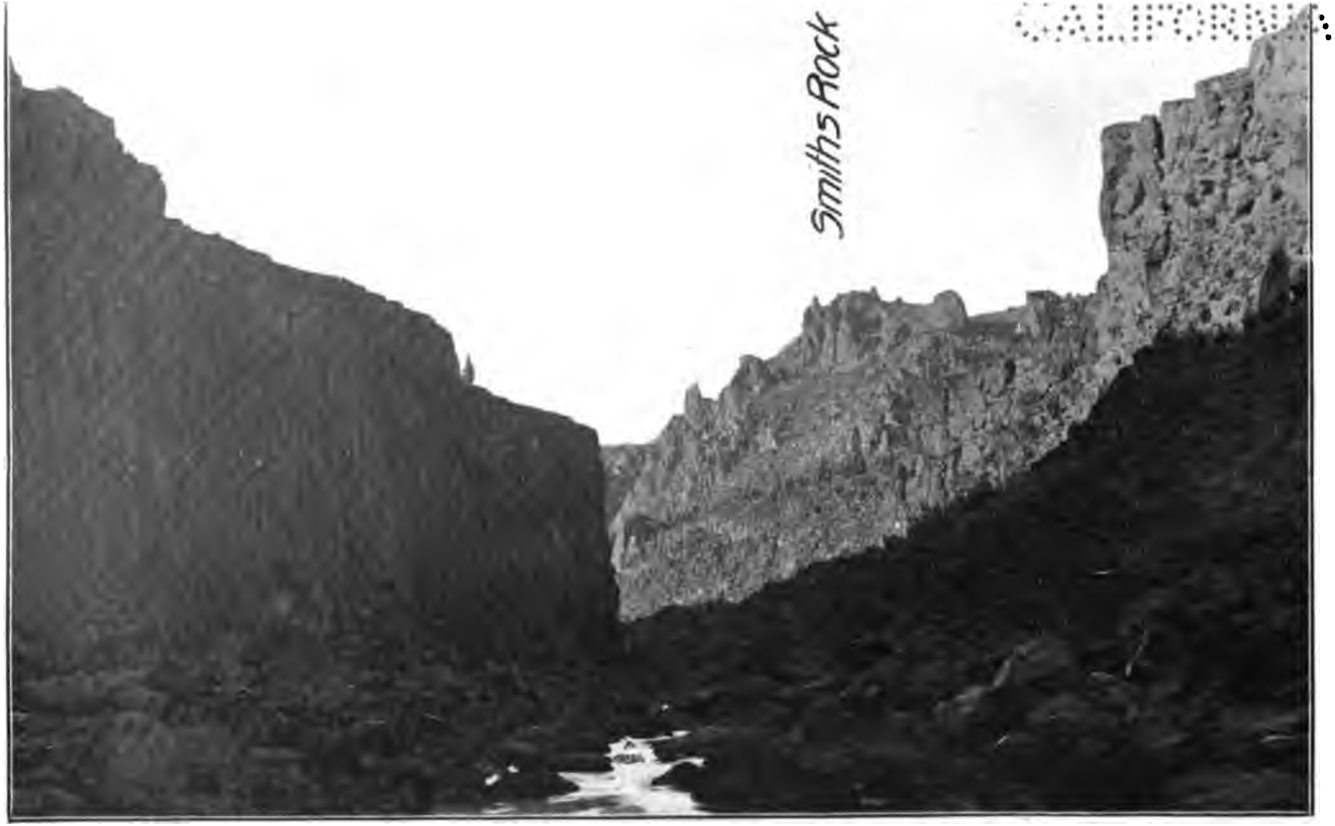
Depth in feet.
0 -10 —Earth and boulders (talus).
10 -12 —Boulders and coarse gravel.
12 -14 —Light, porous tuff.
14 -16 —Compact, solid tuff.
16 -37 —Light, porous tuff.
37 -46½—Compact, solid tuff.
46½-49 —Lost water above 49.
49 —Sand filled hole up to 47.
49 —Bottom of hole.

SURVEYS FOR THE NORTH UNIT.

The lands of this unit have often been reported to be very desirable if irrigated. Possibilities of their irrigation have been considered from time to time, but the necessary investigations have not gone beyond a preliminary reconnaissance survey. Any scheme to use water from Deschutes River involves a diversion dam with a long and expensive canal, including a crossing of the deep Crooked River Canyon, together with several miles of exceptionally difficult and expensive construction about Smith's Rock on the north side of Crooked River, before the first of the irrigable land is reached. On the other hand, any scheme to use water from Crooked River involves expensive storage, together with a long and difficult canal to Smith's Rock, and the same expensive construction around Smith's Rock to the first irrigable lands.

The investment of private capital in large irrigation projects is naturally not attractive under any conditions, for the reasons that the initial outlay necessary before the first irrigable land is reached is large, and the prospective returns are small and must be deferred for many years. For these reasons such capital has not been sufficiently interested to make even a preliminary survey for this North Project.

The discharge records of Crooked River, available at the beginning of these investigations, covered a period of only four years and were quite fragmentary. Discharge records of Deschutes River covered a much longer period. Possession of these records, together with the fact that there was apparently insufficient water from the flow of Crooked River to supply the entire North Unit and



CROOKED RIVER CANYON IN VICINITY OF PROPOSED CANAL CROSSING FOR NORTH UNIT. SMITH'S ROCK IN BACKGROUND.

PLATE VI.

that the expense of storage would be large, made it appear desirable to first investigate and report upon the Deschutes River supply.

The topography of the larger portions of the region lying east of the Deschutes and south of Crooked River, and extending to Powell Buttes on the east and to the Central Oregon Canal on the south, made it possible to determine within narrow limits the location which a canal should follow, between a diversion from Deschutes River and a crossing of Crooked River. See Sheets No. 26, 27, 28, 30, 32 and 33.) There is no question but the crossing of Crooked River should be made at a point immediately above Smith's Rock for two reasons: The one, that any lower crossing of the river would serve a lesser area of land; the other, that at any crossing below this point, the south side of the canyon is lower than the north side, making it relatively expensive to hold the grade on the south side up to the necessary elevation. The proper point of diversion, however, is more indefinite and particularly so if the present North Canal diversion should be used in connection with the irrigation of an East Side Unit, or the North Canal Unit of the Central Oregon Irrigation Company. Further reference will be made to this possibility. From Deschutes River, the canal line survey, beginning at Swalley Bridge, runs down the east side of the Deschutes and around the north end of Long Butte to the Pilot Butte Canal. It then runs parallel with this canal to the town of Redmond and crossing to the east side of the railroad, heads northeasterly to Crooked River at a point about one mile east of Smith's Rock. Crossing the river, the main line survey follows down the north side of Crooked River Canyon, along and around the west and north side of Juniper Butte and swinging around the ends of the two ridges, which run northwesterly toward Round Butte, crosses Willow Creek. Thence it makes northeasterly across Mud Springs Creek near Buck Butte, to the rimrock ridge west of Hay Creek.

In working out probable canal locations for this unit, it was believed that Agency Plains, east of Willow Creek, could be reached by following one of the ridges which run from the main high line immediately north of Juniper Butte to Round Butte. Survey lines were run from the main high line along these ridges to, and around, Round Butte, and from the town of Metolius northerly along the O. W. R. & N. Co. track to Willow Creek. As neither one of these lines appeared to furnish a means of reaching Agency Plains, a third line was surveyed from the main high line, north along the ridge between Agency Plains and Mud Springs Creek, to Deschutes River Canyon, and another from the main high line along the ridge east of Mud Springs Creek, north to the edge of Deschutes Canyon.

SURVEYS FOR THE SOUTH UNIT.

The lands of this unit lie south and southwest of Powell Butte and comprise the major portion of the Benham Falls segregation of the Central Oregon Irrigation Company. Probably endeavors to irrigate these lands are historically the most interesting of all the irrigation schemes in the Deschutes Basin. So far as can be learned, the earliest surveys for any irrigation project to take water from the Deschutes, were made to serve these lands, together with land now irrigated by the Central Oregon Canal, and land about and east of Powell Buttes to Crooked River. However, the early efforts to serve these lands were not due to the superiority of the lands themselves, but were undertaken as the result of the assumption that from a diversion point somewhere near the head of Benham Falls, irrigable land could be reached with a short canal. Surveys always developed the fact that very little irrigable land could be reached short of 30 miles from the diversion, and that the cost was excessive, as the canal ran out across the lava beds east of Benham Falls.

The main canal survey for this unit runs from a diversion point at the head of Lava Island, around the north side of the lava beds referred to, and extends in a generally easterly direction to and across the Dry River Bed and thence north to Crooked River. A canal line to serve the territory around Powell Buttes was run from the main canal line just east of the Dry River Bed, to and around Powell Butte, with a lateral line surveyed from this Powell Butte line, north and around the east side of Grass Butte. See Sheets Nos. 34, 35, 36 and 37.

Topography of the Lava Island diversion dam site was developed and the map plotted on a scale of 400 feet to 1 inch. This topography is shown on Sheet No. 23. No test borings were made at this dam site.

SURVEYS FOR BENHAM FALLS RESERVOIR AND DAM SITES.

The topography of the Benham Falls Reservoir site was developed by a survey made by the United States Geological Survey in co-operation with the State during the year 1911. The scale upon which this topography is shown is one-half mile to the inch. The survey was made with a plane table, using the compass needle for horizontal control and tying in upon a few of the section corners. Because of the local magnetic variation in this region, the map shows the section lines somewhat more distorted than they actually are, but as the work was very carefully done, the distortion, where there is any, does not appreciably affect the estimates of reservoir capacity, or of the cost of construction, necessary for this report. A classification of the canal within the reservoir site was also made at the same time as the topographic survey.

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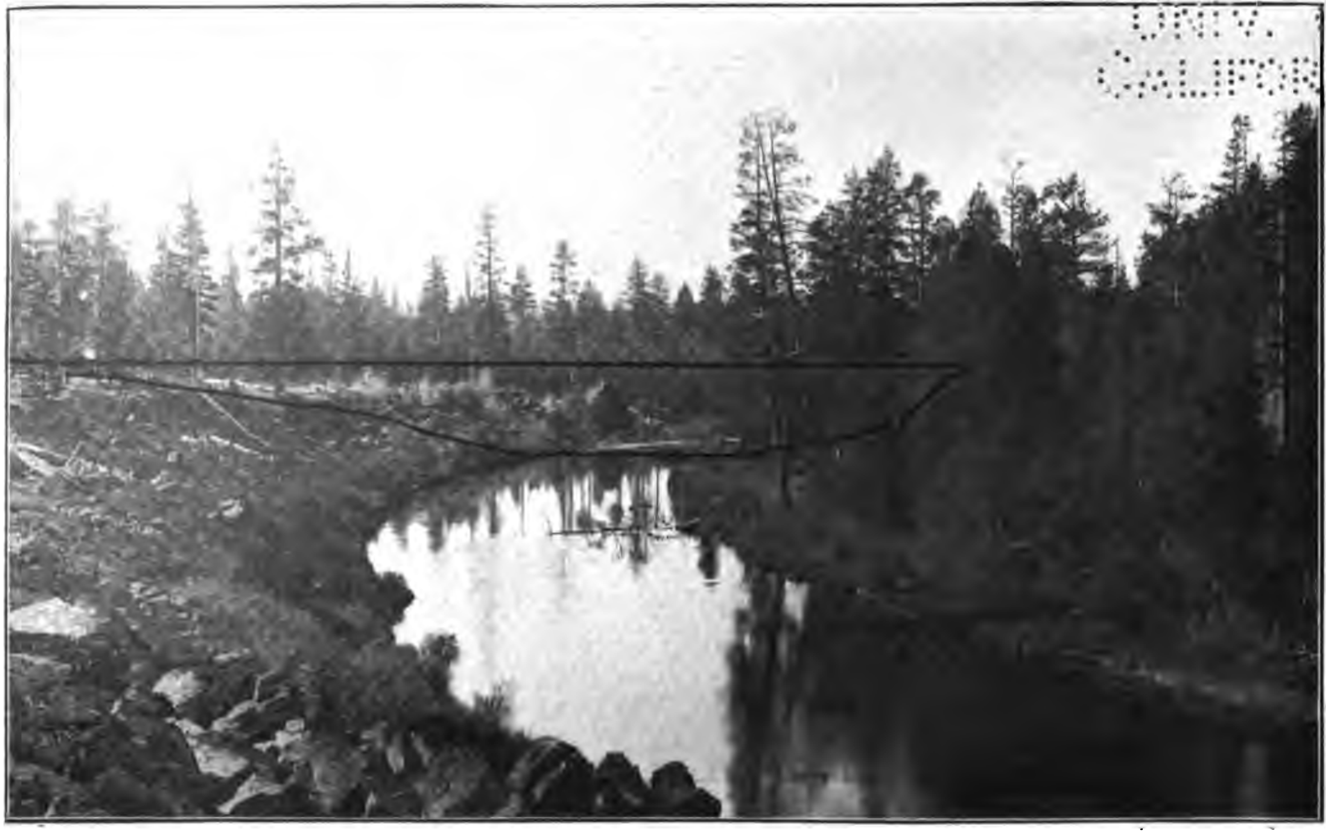


BENHAM FALLS RESERVOIR DAM SITE.

PLATE VII.

been prepared for this report, as such a map would be of material value only at the time that purchase of land was to be made.

Topography of the available dam sites at Benham Falls was developed and is shown on Sheet No. 21. Sites were considered at three places, as shown on this sheet, and designated as Sites A, B and D. Test borings were made at these three sites, see Sheet No. 21, together with single borings at points E, F, G, H, I, J and K, see Sheet No. 69. Tabulation of the records of these test borings is as follows:

Test Borings, Benham Falls Dam Sites—Site "A."

Hole A-1. Surface elevation, 4,146.4 feet.

Depth in feet.
0 -19 —Top soil, sand and pumice, river deposit.
19 -30 —Pumice sand.
30 -40 —Black sand, some pumice sand.
40 -51 —Mud or silt.
51 -53 —Boulder.
53 -56 —Fine black sand.
56 -58 —Same, with particles of clay.
58 -75 —Packed or cemented gravel (probably volcanic).
All water returned above 75.
All water lost below 75.
75 -82 —Loose boulders and gravel of same formation.
82 —Bottom of hole.

June 3-June 9, 1913.

Hole A-2. Surface elevation, 4149.6 feet.

Depth in feet.
0 -12 —Top soil (sand and pumice), river deposit.
12 -52 —Fine sand with some clay (probably silt).
52 -57 —Medium coarse sand, with some clay (probably silt).
All water returned above 57.
57 -77 —Packed or cemented gravel (probably volcanic).
Part of water returned from 57 to 77.
All water lost below 77.
77 —Bottom of hole.

June 9-June 12, 1913.

Hole A-3. Surface elevation, 4150.0 feet.

Depth in feet.
0 -10 —Top soil.
10 -25 —Fine sand, with some clay (probably silt).
25 -35 —Coarse sand.
35 -59 —Fine black sand, with some clay (probably silt).
59 -73 —Packed or cemented gravel (probably volcanic).
All water returned above 73.
All water lost below 73.
73 -76 —Fine black sand.
76 -77 —Packed or cemented gravel.
77 —Bottom of hole.

June 13-June 14, 1913.

Test Borings, Benham Falls Dam Sites—Site "A."—(Cont'd)

Hole A-4. Surface elevation, 4146.0 feet.

Depth in feet.

0 -19 —Top soil (sand and pumice), river deposit.
19 -30 —Pumice sand.
30 -40 —Black sand, some pumice sand.
40 -51 —Mud or silt.
51 -52 —Very clayey.
52 -54 —Black lava boulder, same as bluff on south side of river.
54 -58 —Fine black sand.
58 -74 —Packed or cemented gravel (probably volcanic).
All water returned above 75.
74 -75 —Streak fine sand.
All water lost, 74 to 75.
75 -81 —Same as 58 to 74.
All water returned 75 to 81.
81 -85½—Streak of fine black sand.
About one-half of water lost from 81 to 85½.
85½-91½—Same as 58 to 74, and 75 to 81.
All water returned 85½ to 91½.
All water lost below 91½.
91½-104 —Loose for mation of broken rock and coarse sandy material (probably slide from north side of river).
104 -115 —Large boulder (probably slide from north side of river).
115 -137½—Same as 91½ to 104.
137½—Bottom of hole.

September 10-September 27, 1913.

Hole A-5. Surface elevation 4192.0 feet.

Depth in feet.

0 - 5 —Sand and surface soil.
5 - 17 —Porous lava rock.
All water returned above 17.
17 - 25 —Porous lava rock with seams at the following depths, 17-19-20-21-24 and 25, through which all of water is lost except hole at 20 feet depth, through which only part of water is lost.
25 - 33 —Porous lava rock, all water returned.
33 -33½—Seam, all water lost.
33½-38 —Porous lava rock, all water returned.
38 - 38½—Seam or pocket filled with lava sand, all water returned.
38½- 50 —Porous lava rock, all water returned.
50 - 50½—Seam or pocket of sand, all water lost.
50½- 58 —Porous and shattered lava.
58 - 80 —Porous lava rock.
80 -101 —Solid lava rock.
All water returned 50½ to 101.
101 —Bottom of hole.

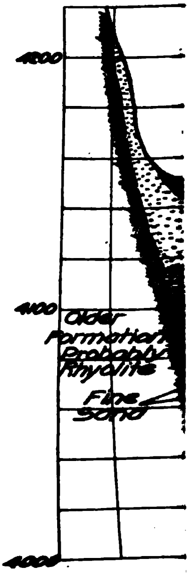
September 15-September 27, 1913.

Hole A-6. Surface elevation.

Depth in feet.

0- 7—Water.
7-15—Lava boulders and broken rock.
All water returned above 15.
15—Bottom of hole.

October 1, 1913.


4200
4100
4000
Older
Formatio
Probabl
Rhyolite
Fine
Sand

Hole
Depth i
feet.
0 -19
19 -30
30 -40
40 -51
51 -52
52 -54
54 -58
58 -74

74 -75

75 -81

81 -85

85½-91

91½-1

104 -1
115 -1
1

Sept

Hole
Depth
feet.
0 -
5 -

17 -

25 -
33 -3
33½-3
38 -
38½-
50 -
50½-
58 -
80 -1

1

Sept

Hol
Depth
feet
0- 7—
7-15—

15—
Oct

Test Borings, Benham Falls Dam Sites—Site "B."

Hole B-1. Bed of river 4143.5 feet.

Depth in feet.
0 - 7 —Water.
7 -15 —Black mud or silt.
15 -22 —Medium fine sand (color red and gray).
22 -32 —Gray clay and mud.
All water returned above 32.
32 -38 —Loose broken lava with sand.
Part of water returned from 32 to 38.
38 -53 —Broken lava rock (hard).
All water lost 38 to 53.
53 -73½—Solid lava rock with close seams.
All water returned 53 to 73½.
73½—Bottom of hole.

June 26-July 24, 1914.

Hole B-2. Surface elevation 4195.5 feet.

Depth in feet.
0 -32 —Porous lava rock (shattered).
32 -41 —Hard lava rock (shattered into fragments).
41 -49 —Boulders (hard lava rock).
49 -65 —Black sand mixed with fragments of lava rock.
65 -75 —Black sand mixed with pumice and fragments of lava rock.
75 -78 —Same as 49 to 65.
All water lost above 78.
78 —Bottom of hole.

Hole B-3. Surface elevation 4153.6 feet.

Depth in feet.
0 -20 —Loose rock and soil.
20 -23 —Fine sand.
23 -37 —Same as 0-20.
All water lost above 37.
37 -41 —Lava rock (hard).
All water returned 37 to 41.
41 —Bottom of hole.

July 15-July 19.

Hole A·

Depth in feet.

0 -19

19 -30

30 -40

40 -51

51 -52

52 -54

54 -58

58 -74

74 -75

75 -81

81 -85½

85½-91½

91½-104

104 -11

115 -13

13

Septe

Hole

Depth i

feet.

0 -

5 - 1

17 - 2

25 - 3

33 -33

33½-38

38 - 3

38½- 5

50 - 5

50½- 5

58 - 8

80 -10

10

Sept

Hole

Depth

feet.

0- 7—

7-15—

15—

Oct

Test Borings, Benham Falls Dam Sites—Site "B."

Hole B-1. Bed of river 4143.5 feet.

Depth in
feet.
0 - 7 —Water.
7 -15 —Black mud or silt.
15 -22 —Medium fine sand (color red and gray).
22 -32 —Gray clay and mud.
All water returned above 32.
32 -38 —Loose broken lava with sand.
Part of water returned from 32 to 38.
38 -53 —Broken lava rock (hard).
All water lost 38 to 53.
53 -73½—Solid lava rock with close seams.
All water returned 53 to 73½.
73½—Bottom of hole.

June 26-July 24, 1914.

Hole B-2. Surface elevation 4195.5 feet.

Depth in
feet.
0 -32 —Porous lava rock (shattered).
32 -41 —Hard lava rock (shattered into fragments).
41 -49 —Boulders (hard lava rock).
49 -65 —Black sand mixed with fragments of lava rock.
65 -75 —Black sand mixed with pumice and fragments of lava rock.
75 -78 —Same as 49 to 65.
All water lost above 78.
78 —Bottom of hole.

Hole B-3. Surface elevation 4153.6 feet.

Depth in
feet.
0 -20 —Loose rock and soil.
20 -23 —Fine sand.
23 -37 —Same as 0-20.
All water lost above 37.
37 -41 —Lava rock (hard).
All water returned 37 to 41.
41 —Bottom of hole.

July 15-July 19.

Benham Falls Reservoir Borings.

Hole E-1. Surface elevation, 4157.0 feet.

Depth in feet.
0 - 2 —Surface soil.
2 -16 —Pumice sand.
16 -23 —Mud (probably silt).
23 —Rock.
All water returned.
23 —Bottom of hole.

Hole F-1. Surface elevation, 4157.0 feet.

Depth in feet.
0 - 2 —Surface soil.
2 -16 —Pumice soil.
16 -25 —Mud (probably silt).
25 -27 —Clayey material.
All water returned.
27 —Bottom of hole.

Hole G-1. Surface elevation, 4148.0 feet.

Depth in feet.
0 -10 —Pumice sand.
10 -27 —Mud (probably silt).
All water returned.
27 —Rock or boulder, bottom of hole.

Hole H-1. Surface elevation, 4151.0 feet.

Depth in feet.
0 - 3 —Top soil.
3 -14 —Coarse lava sand.
14 -28 —Mud (probably silt).
28 -38 —Lava gravel or coarse sand (packed).
All water returned.
38 —Bottom of hole.

October 4, 1913.

Hole I-1. Surface elevation, 4147.0 feet.

Depth in feet.
0 - 7 —Water.
7 -15 —Black sand.
15 -23 —Pumice sand deposit (with decayed wood).
23 -41 —Mud (probably silt).
41 —Black lava rock or boulder.
All water returned.
41 —Bottom of hole.

October 4, 1913.

Hole J-1. Surface elevation, 4146.0 feet.

Depth in feet.
0 - 7 —Water.
7 -14 —Fine river sand.
14 -29 —Pumice sand.
29 -47 —Mud (probably silt).
47 —Cemented gravel.
All water returned.
47 —Bottom of hole.

October 4, 1913.

Benham Falls Reservoir Borings.

Hole K-1. Surface elevation 4144.0 feet.
Depth in
feet.
0- 6—Water.
6-12—Fine sand or silt.
12-25—Fine sand, mixed with pumice.
25-35—Medium sand, mixed with pumice.
35-45—Pumice, mixed with sand.
45-55—Fine sand or silt, mixed with pumice.
55-60—Fine sand or silt.
All water returned.
60—Bottom of hole.
October 6, 1913.

History of the Borings. The first hole was put down at Site A, see Sheet No. 21, and was carried down to about 70 feet. It was expected that within this distance, either the continued slope of the older formation on the west side of the river, or the overlapping basaltic rimrock on the east side would be encountered. Since neither occurred, the drill work was transferred to Site B, see Sheet No. 21, where even less satisfactory conditions were found. Hole No. 2 at this site, passed through the relatively recent lava flow from Lava Butte, into the pumiceous sandy material found near the surface of the holes in the river bottom. Hole No. 3, after passing through talus and other material, encountered the porphyritic rhyolite on the west bank slope, and from this condition it was evident that the river channel, prior to the recent lava flow from Lava Butte, was immediately under that lava flow, and any examination at Site C, the head of the Falls proper, would be useless. It is also to be observed that the surface losses referred to by Russell were all within this portion of the river, and there seems practically no doubt that the river channel, immediately prior to the recent lava flow, lay many hundred feet east of its present location at this site.

Site D was then taken up, and on completion of the investigations here, it became quite apparent that a masonry dam at Benham Falls could not be considered. Work was therefore again resumed at Site A, which offers decidedly better conditions for an earth and rock filled type of dam than either of the other sites.

In putting down test holes, iron pipe with flush joints, called casing, is worked down through all loose material until rock is encountered. Until rock is reached, the material, of whatever character, is either chopped loose with a chopping bit and washed out by water forced through the chopping bit under pressure, or, if hard material, such as cemented gravel or boulders be encountered, the hole is shot down by dynamite which is lowered through the casing and electrically exploded from the surface, first raising the casing a few feet to prevent its being destroyed. In all the bore holes, therefore, there is a test of the water tightness of the material passed through, because if the material is water tight, the water forced through the drill rods under pressure returns outside the drill rods but inside the casing, and is continually under observation by the drill runner.

When any material portion of the water forced into the hole through the drill rod fails to return to the surface, it is immediately noted as indicating that open or porous material is being encountered. No water was lost in these holes until the packed or cemented gravel was reached at about elevation 4,090, see cross section of damsite A, Sheet No. 66.

In hole No. 3 no water was lost until the stratum of fine sand was struck below this packed or cemented gravel. This hole was not shot down, but was chopped through the cemented gravel.

Through the other holes, a little water was lost in the first part of the cemented gravel, but it is probable that none would have been lost above the sand stratum if the cemented gravel stratum had not been shot through, thus opening up fissures through which the water escaped.

Hole No. 4 was put down as a deep hole from the beginning and at a depth of approximately 140 feet ended, in broken rock and boulders.

Hole No. 5, in the basalt rimrock, was sunk approximately 100 feet to determine whether or not the old river channel lies deep enough under this lava flow to be effectively cut off by the water tight material encountered in holes 1 to 4 inclusive, above the stratum of fine sand. It is evident from the cross section that this is the case, and that the ancient river channel must have been at greater depth.

Hole No. 6 had been put down only a short distance when it was concluded that it would furnish no information not already obtained.

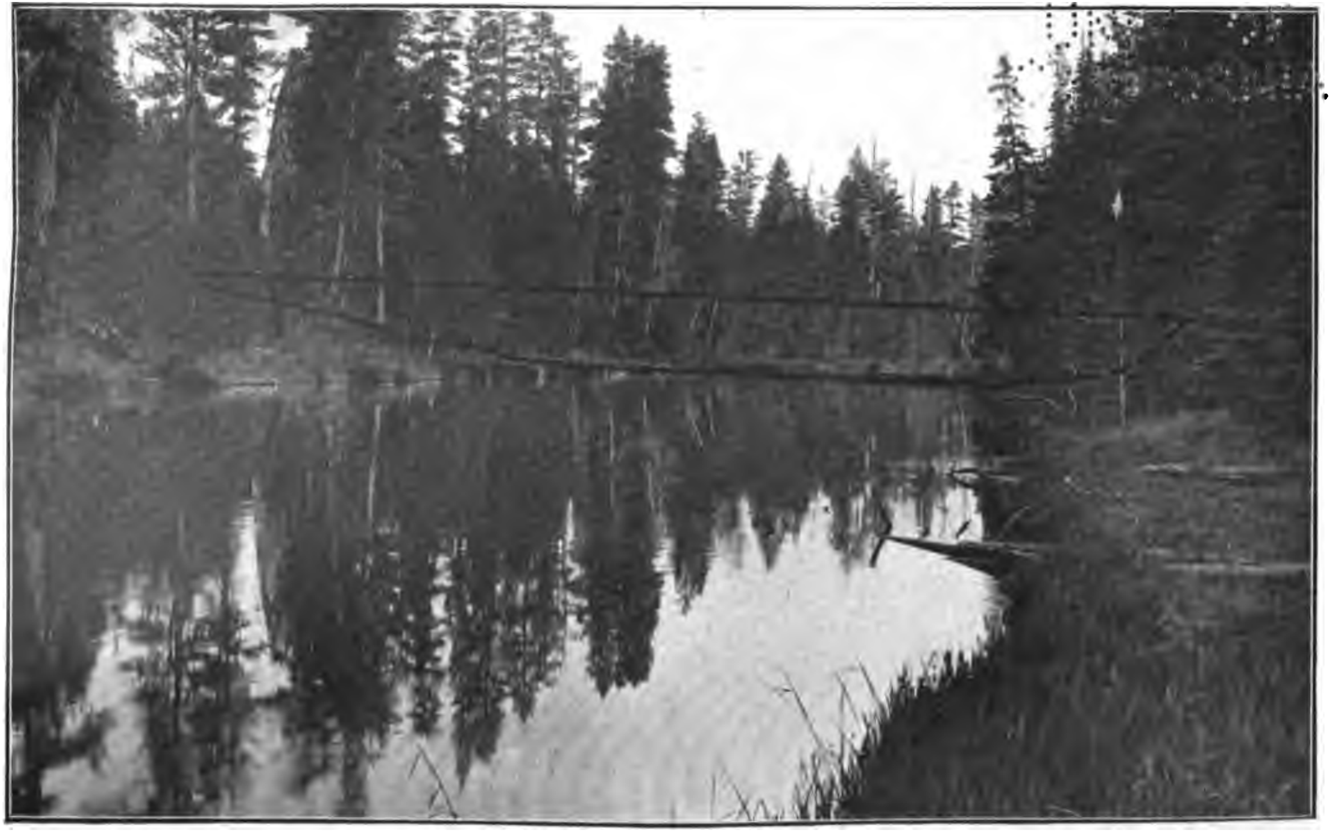
It is of interest to note that in hole No. 4, at a depth of 91½ feet, water in the casing stood slightly below the water surface in the river, thus indicating a less hydrostatic pressure in this lower material than in that above. This is, no doubt, the result of the lower material being directly connected through similar continuous coarse material with some of the older river channels which join the present river somewhere below Benham Falls.

CRANE PRAIRIE RESERVOIR AND DAM SITES.

The only information available with reference to this reservoir site, was a survey made in 1907 for the Deschutes Irrigation and Power Company, in which the reservoir topography was sketched from a single traverse line around the basin. It was not regarded as sufficiently reliable for the purpose of this investigation. A plane table survey was therefore made on a scale of 1,000 feet to the inch, with horizontal control based on plane table triangulation, and vertical control carried up from United States Geological Survey precise level line along the east side of Deschutes River.

PLATE VIII.

CRANE PRAIRIE RESERVOIR DAM SITE.



CRANE PRAIRIE RESERVOIR DAM SITE.

PLATE VIII.

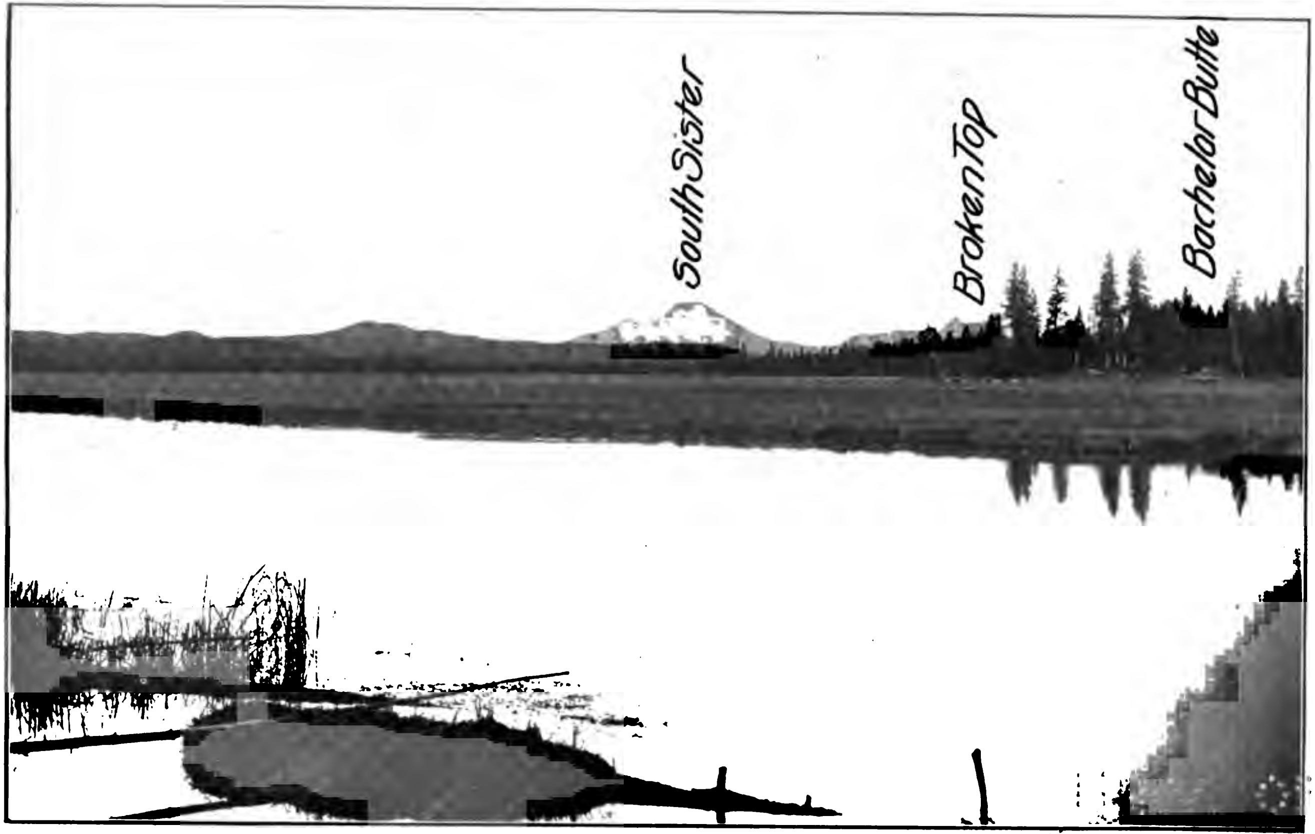


PLATE IX.

CRANE PRAIRIE LOOKING NORTH FROM LOWER END.

CALIFORNIA

Test Borings, Crane Prairie Dam Site—(Cont'd).

Hole A-4. Surface elevation, 4451.8 feet.
Depth in feet.
0 - 3 —Pumiceous sand.
3 - 7 —Lava rock.
7 -14 —Grey porous lava rock.
All water returned above 14.
Lost all water at 14.
14 -20 —Grey porous lava.
20 -25½—Solid lava rock.
25½-38 —Dense grey lava.
38 —Bottom of hole.

August 11-August 14, 1914.

Shaft, Line A. Surface elevation, 4428.7 feet.
Depth in feet.
0 - 3 —Black soil.
3 -17 —Sand rock, soft.
17 -19 —Sand rock.
19 -20 —Sand rock.
20 -22 —Lava boulders, with brown clay.
22 —Bottom of hole.
Material 3 to 20 is watertight.
20 -22 —Water runs in from sides.

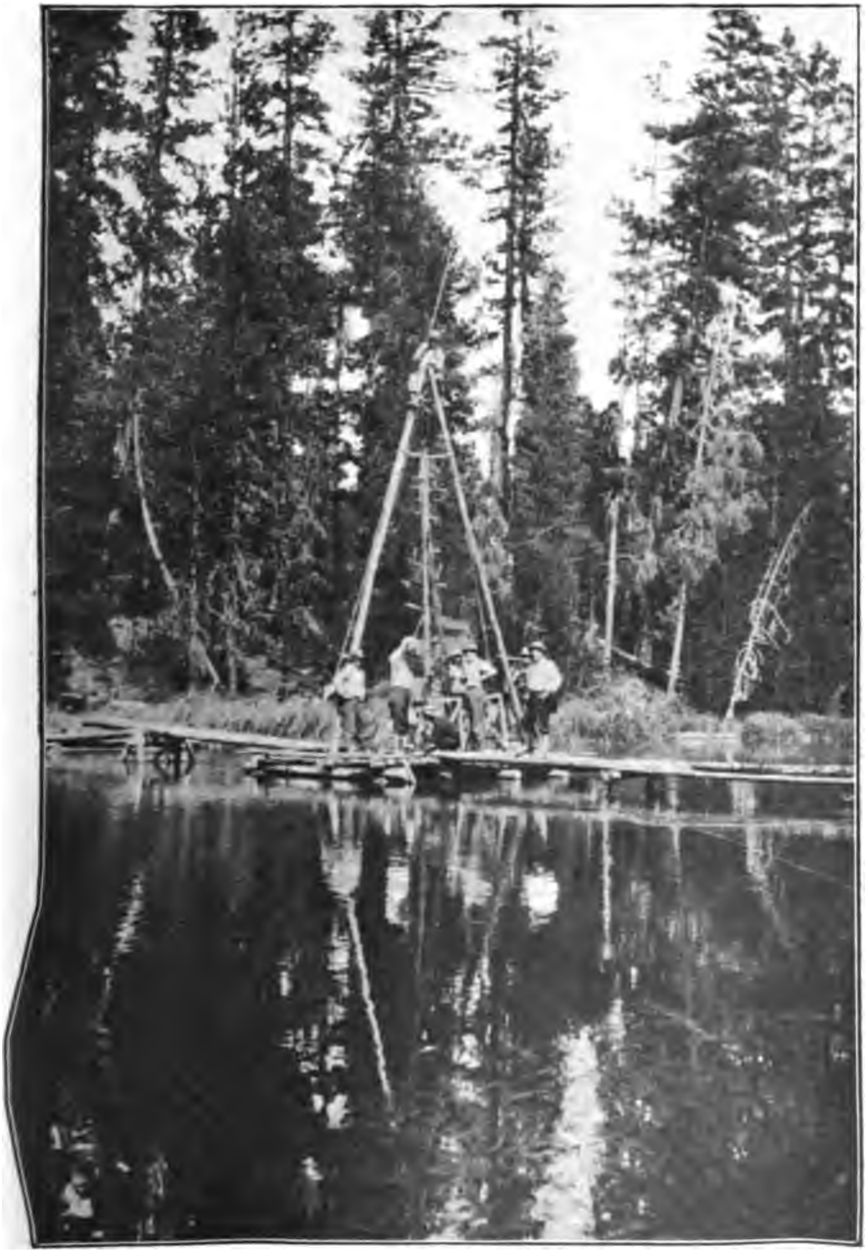
SOILS SURVEY.

A preliminiary soil or agricultural survey of the irrigable lands of the project, was made the latter part of October and early November by W. L. Powers, Assistant Professor of Irrigation and Drainage, Oregon Agricultural College.

Mr. Powers had previously spent one season at Metolius and Redmond on the Oregon Experiment Stations, and was therefore already fairly well informed as to the North, East Side and West side Units. All additional field investigations were completed in one week. The soil survey of the South Unit may be considered as only roughly approximate. For the North and West Side Units, while in no sense was a thorough survey made, it is believed that reasonably comprehensive and representative data has been rendered available.

The physical and chemical analyses of soils were made at Oregon Agricultural College.

Soil survey maps, Sheets Nos. 127, 128 and 129, show soil classifications of the North, West Side and South Units respectively. Detailed descriptions of soils, with analyses and discussion relative to agricultural development under irrigation, are given under "General Discussion of the Problems and of the Development Proposed, Agricultural Survey."



DIAMOND DRILL AT CRANE PRAIRIE DAM SITE.

PLATE X.

General Discussion of the Problems and of the Develment Proposed.

RELATION BETWEEN WATER RIGHTS AND WATER REQUIREMENTS.

It is impossible to determine the ultimate use of water for a proposed irrigation project prior to the completion of the project. Despite the best possible preliminary examinations of soil characteristics, there must yet remain much uncertainty as to its ability to retain or pass moisture, and the consequent requirements of irrigation supply for plant life, as well as the possibilities of seepage losses and return flows into the streams.

In addition there are the uncertainties of the human element in the matter of economical or wasteful use of water, as well as much doubt as to the nature of the crops that will prove most profitable in any particular locality, all of which factors have an important bearing in the use of, or requirements for water.

In determining the question of storage requirements for a given project, other elements of great uncertainty enter into consideration, such as: The ability of irrigation companies to complete the construction program contemplated; the eventual trend of colonization and agriculture in different localities, and the added uncertainty as to the results of adjudication proceedings, involving not only the use of water for irrigation, but the relative priority of water rights for power development and domestic supply.

Certain assumptions covering these conditions are necessary before plans, which contemplate the full utilization of the run-off of a stream, can be worked out. However, the assumptions that are herein made must not be considered as an individual judgment of the present legal rights of the water appropriators.

For example, a company or district may have a legal permit to divert and use water for the irrigation of 10,000 acres of land, and have an unlined canal of apparently sufficient capacity to serve these lands. The seepage losses in this canal, however, may be so great that it will only serve 5,000 acres. The solution of the question as to whether the canal system will eventually be so improved that with the water diverted the entire 10,000 acres of land will be served, or whether under a water adjudication of "beneficial use" the excess water diverted and wasted in canal seepage is appropriated to other use, is not expressed in the assumptions made for the purposes of this report.

Cases have been known where technical legal rights have been acquired under old appropriations for many times the actual amount of water flowing in a stream; nevertheless it may be quite apparent that the appropriators are not using, and could not possibly use, more than half of the actual flow. In determining possibilities of the full utilization of the runoff from such a stream, it is therefore necessary to ignore the amount of the old appropriations claimed, as useless and misleading, and to assume that one-half of the runoff remains for further appropriation.

Under the laws of the State of Oregon, the rights of water appropriators are adjudicated by the State Water Board and the courts, from evidence, and such rights must be based on actual beneficial use.

IRRIGATING SEASON.

In the Tumalo Project the State proposed to furnish 1.8 acre-feet of water per acre measured at the land.

The State Desert Land Board, in its Carey Act contracts, has generally required in this locality the delivery of 1.8 acre-feet of water per acre, measured within one-half mile of land, for the 90-day period, May 23 to August 20, inclusive, together with as much water, before and after this period, as may be required for best agricultural development.

The maximum rate of delivery necessary determines the capacity of the entire canal system. It is therefore to the interest of the irrigation company to extend over as long a period as possible, the season during which any given volume of water is to be delivered. It is also in the interest of the water user himself, who ultimately pays for the construction, to limit the maximum delivery as much as is consistent with good results.

The assumption of an irrigating period of six months, however, seems unnecessarily long for a region of this altitude, with so short a growing season.

Observations and measurements by H. P. Farmer, of Office of Experiment Stations, United States Department of Agriculture, covering some 20 irrigated farms under the Central Oregon Irrigation Company's system in 1912, indicate an average water use curve of approximately the same amount in each of the months of June, July and August, and about half this amount each in the months of May and September.

Under the Central Oregon Irrigation Company's system, the users are given practically all the water they ask for, up to the capacity of the canal system. It is probable, therefore, that the proportionate use, in both May and September, was somewhat larger than best methods would require. It fixes, however, fairly well, the length of irrigating season as beginning with a small use early in May, and a use in September, decreasing to nothing some time before the end of that month. In general, this season has been adopted, with slight modification in each unit, for this investigation.

SEEPAGE AND EVAPORATION LOSSES IN CANALS AND RESERVOIRS.

The evaporation from the water surface of reservoirs and canals in the Western United States will ordinarily amount to 3 feet or more in depth per annum. This amount is considerable in a reservoir, but is so small in a ditch as to be quite negligible. For example, the water surface area of the Umatilla Project feed canal, which is about 25 miles long, is in round numbers 100 acres. With an evaporation of 1 foot in depth per month, a rate which might be reached in the driest part of the year, the total evaporation for one month would be only 100 acre-feet. The amount per day would be 3.3 acre-feet, equivalent to a loss of 1.6 cubic feet per second in the entire canal. The capacity of the canal is 300 cubic feet per second. The per cent of flow lost in the entire canal, due to surface evaporation alone is, therefore, approximately one-half of 1 per cent, thus establishing the loss of flow from evaporation in each mile at about one-fiftieth of 1 per cent, which is insignificant. Canal evaporation loss in this discussion will, therefore, be included in seepage losses, and in fact is, of necessity, actually so included in any measurements made to determine seepage losses.

Natural laws, governing rates of percolation of water through porous material such as soils, sand, and gravels, which ordinarily constitute the beds of canals, have been determined during recent years with a fair degree of accuracy.

In any given material, percolation rates vary almost directly as the head of water; thus, in any given cross section of canal, in material of ascertained character, the total percolation should theoretically be a direct factor of the wet perimeter, the average head, and the length.

As a matter of fact, other elements enter very largely into this question, particularly the effect of surface puddling and silting along the perimeter, due to wave action, and the straining out or deposition of fine material carried in suspension. The formation of a film or surface skin of micro-organic matter, such as is formed on the surface of all sanitary filters, and is effective in aiding the nitrification of organic impurity, will necessarily result during use of a canal. All of these causes tend to retard percolation and so greatly influence the general result, that for practical purposes it would be inadvisable to attempt to determine percolation by direct application of the above rule.

It is probable that, with the slow rate of percolation through the bottom and sides of most canals, capillarity of the adjoining material has a very important part in affecting the rate of seepage loss. However this may be, observations lead to a fairly definite conclusion that seepage losses in canals and ditches are almost directly proportional to the wet area of the canal. and that the depth or head very slightly. affects the losses within the limits of ordinary canals.

The amount of water lost by seepage in the small laterals which directly serve the farms, is sometimes proportionately very much to nearly one-half.

In the Truckee-Carson and Klamath Projects the canal losses have been found to be larger. In the Orland, Tieton and Sunnyside Projects the canal losses have been only about one-third of the water diverted.

Determinations of duty of water have frequently been made from measurements, either at the diversion point, or at some point between the diversion and the actual point of delivery to the lands, usually at the head of laterals, with the result that actual losses between diversions and lands have often been under-estimated.

As pointed out above, the losses in the smaller laterals are sometimes comparatively large and may easily exceed all other losses combined.

Newell and Murphy in "Principles of Irrigation Engineering," state:

> "The results of observation on this subject while not conclusive, seem to show that the average seepage loss from canals carrying more than 100 cubic feet per second is less than 1 per cent per mile. While for canals carrying less than 10 cubic feet per second the average losses exceed 10 per cent per mile * * *.
>
> Some investigations have been made to determine seepage losses in terms of wet area. These results show losses varying from about 0.25 to 6.0 cubic feet of water per square foot of wet area per day. In some cases, however, the daily rate of seepage varies from about 0.5 to 1.5 cubic feet per square foot of wet area."

The following is a quotation from a paper by E. G. Hopson on "The Economic Aspect of Seepage and Other Losses in Irrigation
ystems," in Vol. 76, Transactions of the American Society of Civil
gineers:

> 'In 1910 and 1911, a lateral on the Umatilla Project was lined with
> ar, 1 inch thick, and careful measurements were made to determine the
> The lateral had been selected for lining on account of the very
> character of its bed, and in order to reduce seepage loss. With the
> closed at the ends by dams, measurements showed that the water
> lowered about 0.1 feet each day in the lined ditch, and by applying
> of loss to the canal system as a whole, making due allowance for
> of flow, it was computed that the aggregate seepage loss in the
> f all the canals were lined, would be about 5 per cent of the
> Vith the unlined system the loss is close to 50 per cent. Subse-
> urements have confirmed the above, and, from these and other
> onclusion has been reached that seepage losses can be kept down
> 10 per cent of the amount diverted, if good linings are placed."

portions of the Central Oregon and Pilot Butte canals of
regon Irrigation Company appear to be as high as 10 to
er mile. The contract between this company and the
measurement of water within a half mile of the land
ements have shown some very large losses between
and land, and the use of 3 to 4 acre-feet per acre,

measured at the company measuring box, might be 2 to 3 acre-feet per acre measured at the land.

Reservoir seepage losses vary from practically nothing to as much as over 60 per cent of the water stored. See Trans. Amer. Soc. Civil Engineers, Vol. LXXVI, pages 344-7. In general, seepage losses from reservoirs lying in alluvial stream channels are small, while those from reservoirs occupying natural depressions above the plane of stream deposit are large.

The various causes or factors entering into the evaporation losses from reservoir surfaces, have not been well determined, largely because of the impossibility of actual measurement except in combination with losses from seepage. Much time and study has been given the subject by engineers, and many series of evaporation pan records under various conditions have been made, but the general opinion is that none of the methods or formulas so far developed are reliable. The amounts are generally believed to vary between about 3 feet in depth per annum in the highest altitudes of the arid section of the United States, and probably 6 feet in depth in the lower and drier regions. See "Salton Sea Observations" by Frank H. Bigelow, Annual Report, Department of Agriculture, 1909 and 1910.

Assumptions for reservoir seepage and evaporation losses are made under discussion of individual reservoirs.

DUTY OF WATER.

Probably no subject, relating to irrigation engineering, is so much a question of personal judgment for each individual project or tract of land prior to actual experience with that project or tract, as is the duty of water. Actual uses of water vary from depths of less than 1 foot to more than 10 feet for the irrigating season.

In the earlier years of irrigation in any locality, there is the natural feeling of the water user that he can make no mistake by having a large allowance of water for his particular piece of land. He reasons that if his land does not require this amount in the future, he will not be compelled to use it, but if his land does require it and his allowance is too small, it will always be difficult, and frequently impossible, to obtain an increase. As a result of this condition or attitude on the part of the water user, claims for water requirements are, with rare exceptions, placed too high by him. On the other hand, results obtained by unprejudiced experimenters for determining the most economic use of water, have the tendency to be such as can be obtained only under ideal conditions. It is probable that the most economical duty of water lies between the claims of the average water user and the duty determined by the experimenter.

Considering the great damage usually resulting from the use of an excessive amount of water, such as the leaching out of nitrogen and other elements of fertility, and the waterlogging of lower lands, with resulting expensive drainage systems, the proper duty of water f any project is probably nearer that determined by the experiment than that of even the more careful water users. The duty of wat varies with the character of the soil, climate and crops.

In a general way, where as many as three crops of alfalfa can grown in a season, the amount of water required will be very nea twice that for grain. The requirement for orchards of decidu fruit will be roughly the same as for grain. The orchards, howev requiring water later in the season, will more generally requ storage.

Duty of water is expressed both in units of volume per unit of a for the season, as for example, 2 acre-feet per acre to land dur the season, and in rate of use for a fixed period, as for exampl second feet per 100 acres for a season of 100 days. As a compari between these two expressions, it may be noted that a continu supply of 1 second foot for 100 acres through an irrigation sea of 100 days, amounts to 2 acre-feet per acre, or vice-versa.

Another unit of expressing a duty of water in rate of use is miner's inch. This unit obtains, or has obtained in the past, in mining states. The value of a miner's inch in volume of wate very uncertain. It varies in the different states from about 38 50 miner's inches for one cubic foot of flow per second, depend upon the method of measurement peculiar to each State and u various interpretations by the courts of its actual value. The min inch in Oregon is equivalent to one-fortieth of a cubic foot per ond. The use of the term, miner's inch, especially in irrigation gradually going out of use.

For purposes of comparison in any given locality, the expres of "duty" in depth of water per season, which is equivalent to a feet per acre, is probably the best, but for comparisons of diffe localities, having entirely different lengths of season, an expres of rate of use for stated periods would seem to be preferable.

In the following plans and estimates for the Deschutes basin, d of water will be expressed in feet of depth or acre-feet per acre gated.

Where storage of water is not involved, the design and const tion of a project is controlled by the maximum rate of use of wa For example, if the maximum demand for water is at the rate of acre-feet per acre per month, the canal system must be designe deliver this rate of supply, and it is immaterial how much wate delivered before or after this period, so long as it does not exc this rate. It is only when the supply directly from the stream f short of the maximum demand, and when storage is required, t the irrigating period or the amounts used in other months are interest.

In fixing on a duty of water for the various features considered in the Deschutes basin, reference has been had, not only to actual uses of water on lands now irrigated in this locality, but to other older irrigated lands in other localities.

In a paper by Don H. Bark, Engineer in Charge of Irrigation Investigations for the Department of Agriculture, at a Boise Conference of Operating Engineers, in January, 1913, the results are given of some very extended and careful observations covering three years, on 400 individual tracts in the Snake River Valley, with soils ranging from clay to sandy loams, and altitude from 2,350 to 4,950 feet.

The entire report of this Boise Conference of Operating Engineers is of value in considering any irrigation project in the Northwest, but as it is not available in printed form, the most essential part of Mr. Bark's paper on duty of water is given here:

AVERAGE DUTY OF WATER DURING THE YEARS 1910, 1911 AND 1912.
(Bark)

Class of Soil	Crop	Season	No. of Plots	Depth of Water Applied During Season Feet	Average of three Years Feet
Medium Clay and Sandy Loam Soil	Grain	1910	39	1.556	
	"	1911	49	1.172	
	"	1912	34	1.623	1.45
	Alfalfa	1910	17	2.540	
	"	1911	18	2.783	
	"	1912	11	2.160	2.50
Porous, Sandy and Gravelly Soil	Grain	1910	16	3.093	
	"	1911	14	3.088	3.09
	Alfalfa	1910	10	7.130	
	"	1911	7	6.500	6.815

SUMMARY OF DEPTHS OF WATER IN FEET, APPLIED BY MONTHS TO 168 FIELDS OF GRAIN AND ALFALFA, ON MEDIUM CLAY AND SANDY LOAM SOILS.
ALTITUDES RANGING FROM 2,400 TO 3,000 FEET.
(Bark)

Crop	Season	No. of Pl.	April		May	June	July	Aug.	Sept.		Total for season
			1-15	16-30					1-15	16-30	
Grain ...	1910	39	.000	.000	.320	.6453	.495	.0954	.000	.000	1.556
Alfalfa ..	1910	17	.053	.018	.531	.7200	.602	.5510	.064	.000	2.540
Grain ...	1911	49	.000	.000	.021	.7170	.428	.0060	.000	.000	1.172
Alfalfa ..	1911	18	.000	.025	.525	.3080	.945	.7500	.199	.031	2.783
Grain ...	1912	34	.000	.000	.000	.9140	.650	.0590	.000	.000	1.623
Alfalfa ..	1912	11	.000	.000	.508	.4430	.697	.4740	.037	.000	2.160
Average			.009	.007	.318	.6243	.636	.323	.050	.005	1.972
Pct. of total ..			.46	.36	16.08	31.67	32.23	16.38	2.54	.25	100.0

SUMMARY OF DEPTHS OF WATER IN FEET, APPLIED BY MONTHS
POROUS, SANDY AND GRAVELLY SOILS.
ALTITUDES RANGING FROM 2,600 TO 4,825 FEET.

(Bark)

	April	May	June	July	August	September		T
	16-30					1-15	16-30	se
Average	.163	.672	1.514	1.311	1.238	.055	.00	
Pct. of total...	3.39	13.57	30.57	26.47	24.99	1.11	.00	1

General Summary. (Bark)

1. The duty for projects planted to diversified crops on the average loam soils of South Idaho should be sufficient, so that two acre-feet per may be retained on the land.
2. Very impervious soils or shallow soils require slightly more water deep medium soils.
3. A tight, impervious subsoil that roots can penetrate, increases the
4. More water is required where porous subsoils exist.
5. Gravelly soil may require two or more times as much water as the me soil, the amount depending upon the porosity of the soil, the distance wat flooded, and the preparation of the land for irrigation.
6. As much as 80 per cent of the water applied to gravelly soil is somet lost to the use of the crops from deep percolation.
7. Gravelly soils should be irrigated by flooding large heads of water distances.
8. Cultivated crops, all other things being equal, require less water uncultivated crops.
9. Winter grains require less water than spring grains.
10. The time of application has a decided effect upon the yield of grai
11. Alfalfa, clover, and pasture require almost exactly twice as much on the same soil as the grains.
12. An average of approximately 20 per cent of the amount applied is w from grain and alfalfa on the clay loam soils.
13. Diversification of crops greatly increases the duty.
14. Very little water is required by a project either earlier than Ma later than August.
15. The need for water is not constant during the season for a project diversified crops; about 1 per cent of the season's supply is required during A 16 per cent during May, 32 per cent each month during June and July, 16 per during August, and 2.5 per cent during the first half of September, after there is very little need for water.
16. Approximately 64 per cent of the total supply for the season is requ by a project devoted to diversified crops, during the months of June and
17. Rotation systems increase the duty and have many other advantage
18. Most canals divert more water than is actually required, both early late in the season.
19. The amount of water that will produce the largest yield of a certain on a certain soil, is not always the Economic Duty.
20. The value of land, the cost of water, the value of the crops produced, the cost of producing them, as well as the amount of water that will pro the largest yield, must all be taken into consideration when determining Economic Duty for any project.

Particular attention is directed to paragraphs 19 and 20 of Bark's summary. To illustrate the point made in these two p graphs; a certain increase in the amount of water supply for an gation project might make it possible to increase the yield 10 cent. The conditions might be such, however, that the obtainin this increased water supply would increase the cost 30 or 40 per The surplus yield, therefore, from the increased water supply o per cent would be costing three or four times as much per uni measure, as the yield obtainable without the increased water supply, which is ordinarily considerably more than it is worth.

Looking at it in another way, the total water supply available from a given stream may be sufficient to produce the maximum yield from 200,000 acres. The irrigable area available may be 250,000 acres in extent.

By a 20 per cent decrease in the amount of water to each acre, the water of this stream could be made to supply the entire 250,000 acres. While the yield per acre would doubtless be somewhat less, the area irrigated and improved would have been increased 25 per cent, the total yield probably increased, and the actual wealth of the State thereby made greater in the lesser use of water per acre.

In general, therefore, it may be said that the economic duty to be assumed for a project is something less than that which will produce the greatest yield per acre, provided there is other land or other use for the excess water.

Reference has been made to observations on some 20 different tracts of land under the Central Oregon Irrigation Company system by Mr. H. P. Farmer of the Office of Experiment Stations, Department of Agriculture. The uses of water, measured at the Company's measuring boxes, at varying distances, not exceeding a half mile from the land, were from about one and one-half acre-feet to six and one-half acre-feet per acre for the season. The average use for the 20 tracts observed was a little over four acre-feet per acre. Too great weight, however, should not be given to these observations, as the majority of tracts had been irrigated for only one and two seasons, and, in the earlier years of an irrigation development, when the supply is more than ample for all users, there is no incentive to limit the use of water to the contract requirements. The water users themselves are usually inexperienced on new projects and are disposed to argue that if a little water produces such good results, more will do still better.

Experiments and observations during the year 1913 have been made in this locality under the direction of the Oregon Agricultural College. The results of these investigations will be found in Oregon Agricultural Experiment Station Bulletin No. 117.

The duty of water in the plans and estimates of this report, based largely on the data quoted or referred to, has been fixed at 2.0 to 2.5 acre-feet per acre, delivered at the farm, for the different units.

DOMESTIC WATER SUPPLY.

Over the larger portion of the Deschutes basin north of Benham Falls, ground water for domestic supply is found only at great depths. Much money has been spent by the town of Redmond in trying to develop a domestic supply for the city from wells, without success. The supply for the town now comes from Deschutes Riv by pumping.

The wells for the railroad water tanks at Metolius and Culver a said to be 700 to 800 feet deep. Over parts of the land on the we side of the river, water is obtained at reasonable depths; also in t foothills of Gray's Butte and along the upper basins of Willow a Mud Springs Creeks. These creeks are such in name only, exce during the winter and early spring.

It is necessary, therefore, in any irrigation project on the east si of Deschutes River, and, at least, desirable on the west side, provide for a domestic supply from the canal during the non-irrig ing season.

The actual amount consumed for domestic supply is, of cour relatively small, but it will be necessary to carry the water over t entire system of canals. For the small amount delivered, therefo the loss will be proportionately very large, and it will not be unr sonable to assume that from 10 to 20 per cent of the total supply the lands will be properly chargeable to domestic and stock supp

For the purposes of the plans and estimates of this report, t amount required at the land has been assumed as such that th will be required at the diversions, for this specific use, 0.5 acre-f for each acre of land in that unit.

ASSUMED PRIORITY OF WATER RIGHTS.

From the discharge records of Deschutes River at Benham Fa it appears that the supply of water for irrigation from the natu flow of the river without storage does not exceed 450,000 acre-fe while that available for irrigation development with storage is 1,21 000 acre-feet.

The area of land now being irrigated and contracted to be i gated with water diverted from the natural flow of the river is proximately 115,000 acres.

In addition, the Des Chutes Land Company has contracted to i gate approximately 30,000 acres of land above Benham Falls un a plan by which the natural flow is supplemented by storage p vided at Crescent Lake.

The duty of water for these several systems during the irrigat season, as measured at the land and expressed in feet of depth, been estimated at amounts varying between 2.0 feet and 2.5 feet different localities and conditions.

At the present time, seepage losses in the Swalley Ditch exceed per cent of the water diverted from the river; in the Arnold Di they exceed 60 per cent; and in the Pilot Butte Canal, Central O gon Canal and North Canal, the seepage losses are not less than per cent of the water diverted. It is difficult to forecast what use of water in the Des Chutes Land Company project will be, account of the uncertainty of the effect of ground water. The use of an excessive amount of water may cause serious waterlogging of the lands below. The use of water assumed is on this account lower than for the other projects. It may be expected that because of the porous soils that obtain in that vicinity, the return flow to the river from this project will easily amount to one-third or even one-half of the total quantity of water diverted, depending on the actual irrigation use.

There is a possibility that some seepage return from the Arnold Ditch, the Swalley Ditch, and the Central Oregon Irrigation Company's canals may enter Deschutes River above a diversion at or near Laidlaw. Nevertheless, as the general slope of the land in this region is away from Deschutes River, it is believed more likely that this seepage will largely return to the Crooked River drainage.

For all projects, excepting that of the Des Chutes Land Company, allowance has been made for domestic use during the non-irrigating season, including the resulting seepage losses, of a depth of water equivalent to 0.5 of a foot measured at point of diversion.

The mean duty and total use of water assumed for the Arnold Ditch, Swalley Ditch, Central Oregon Irrigation Company canals, the Des Chutes Land Company and other small appropriations, are as follows:

		Duty in acre-feet per acre		Diversion in acre-feet		
	Area	At land	At diversion	Irrig. season	Non-irrig. season	Annual
Irrigation projects initiated	145,000	2.2—	4.0—	532,500	57,600	590,100

40 per cent seepage return estimated for DesChutes Land Company.

The estimated total annual consumption of water for the several projects is thus 590,100 acre-feet, and assuming that storage is provided to utilize the fluctuations in the annual flow of the river up to the mean annual flow of 1,210,000 acre-feet, there remains for further appropriation, including reservoir seepage and evaporation losses, 620,000 acre-feet.

The total area irrigated and contracted for is, from our assumptions, 145,000 acres and is provided for by a diversion of water equivalent to a duty of approximately 4.1 acre-feet per acre. If a duty of 4 acre-feet, including reservoir evaporation and seepage, is assumed for future projects, it will be possible to irrigate approximately 160,000 acres additional from the flow of Deschutes River above Benham Falls.

The monthly runoff of Deschutes River at Benham Falls during the irrigating season from May to September, inclusive, for the years 1905 to 1914, is as follows:

RUN-OFF OF DESCHUTES RIVER AT BENHAM FALLS DURING T IRRIGATING SEASON.

Year	May	June	July	Aug.	Sept.	T
1905	124,000	108,000	105,000	99,600	96,400	53
1906	113,000	105,000	95,900	86,700	81,500	49
1907	154,000	140,000	124,000	114,000	105,000	63
1908	125,000	119,000	116,000	103,000	96,400	55
1909	110,000	107,000	98,400	94,100	90,400	49
1910	122,000	104,000	99,000	94,700	89,300	50
1911	103,000	102,000	92,200	84,800	82,700	46
1912	116,000	128,000	111,000	104,000	99,400	5
1913	117,000	119,000	112,000	103,000	96,600	5
1914	104,000	93,400	84,800	80,600	80,900	4
*Mean	118,800	112,540	103,790	96,450	91,860	5

*Attention is called to the fact that at the time Bulletin No. 2, the adv report on the West Side Unit was prepared, discharge records for 1914 wer available, and that the mean and minimum monthly discharges during the irri season therein set forth, should be modified to agree with the tabulation her

The assumed monthly use of water during the irrigating s for the present projects diverting water below Benham Falls follows:

May	June	July	Aug.	Sept.	Annu
82,900	107,150	126,970	107,150	45,330	469,5

It is apparent that with the ultimate assumed development o present projects, and unless seepage losses are reduced, that tinct midsummer shortage will occur if no provision is mad storage. This shortage will probably necessitate a greater u water in May and September and possibly an extension of the p of irrigation.

IRRIGATION DEVELOPMENT PROPOSED.

It is proposed to store water in reservoirs to be provided at Prairie and Benham Falls. The total runoff of Deschutes Rive available for use directly from the river will be so stored and sion made for the irrigation of about 168,000 acres of land, as fol

First. With diversion at head of Lava Island Falls and canal ning east about 35 miles, then north to Powell Buttes, and se approximately 48,000 acres, called the South Unit.

Second. With diversion a short distance above Aubrey Falls dam raising the water approximately 60 feet, and canal nort serving about 20,000 acres north of Cline Buttes, called the Side Unit.

Third. From same diversion dam at Aubrey Falls, with can proximately 18 miles to Crooked River above Smith's Rock, then around Juniper Butte and north to Gateway and Agency Plains, ing approximately 100,000 acres north of Crooked River, calle North Unit. See Sheet No. 115.

WEST SIDE UNIT.

The larger West Side Unit herein proposed covers an ar 20,325 acres. The irrigable areas are shown on Sheets No. 29, 3

32 and 33, by diagonal hatching. As will be noted, the areas are much broken and scattered. These lands lie generally between high, isolated table land and rimrock "islands," which are, as a rule, too high to reach and often practically without soil. The soils of the irrigable area are probably largely wind-blown and appear to contain rather more humus and alluvial matter than other soils found in this region.

The southeastern portion of the area shown on Sheet No. 31, and practically all of that shown on Sheet No. 32, was eliminated from this unit because it had already been provided for under the State Tumalo Project. The southwestern portion of the area shown on Sheet No. 31, about the town of Sisters, was eliminated because considered too expensive to irrigate, partly owing to the cost of serving, unless other lands north of Squaw Creek were taken in, and partly owing to the cost of clearing and grubbing these lands, which are largely covered with timber. Furthermore it is believed that when additional lands about Sisters are irrigated, they should be supplied with water from Squaw Creek and that land about the mouth of Squaw Creek which it is proposed to irrigate, together with that already partly irrigated with water from Squaw Creek, should be served by the West Side Unit here proposed. In accordance with this policy, an area of approximately 3,500 acres, at present under the Squaw Creek Irrigation Company project, has been included in this West Side Unit.

Water Required. The assumed monthly acre use of water during the irrigating season, measured at the land and expressed in feet of depth, is as follows:

May	June	July	Aug.	Sept.	Total
0.4	0.5	0.6	0.5	0.2	2.2

Assumed seepage losses in distribution laterals have varied from 15 to 30 per cent of the water delivered to their heads, according to the nature of the material through which the canal passes. Seepage losses in the main canals have been assumed as one foot in depth per day over the wetted area for unlined sections and one inch in depth per day over wetted area for lined sections.

The resulting assumed monthly acre diversion requirements are as follows:

May	June	July	Aug.	Sept.	Total
0.63	0.785	0.94	0.785	0.31	3.45

For domestic use during the non-irrigating season, an allowance of 0.5 of a foot in depth per acre, measured at the point of diversion, has been allowed for this unit.

The total assumed diversion requirements for the West Side Unit for the year, expressed in acre-feet, are as follows:

May	June	July	Aug.	Sept.	Tot
12,700	16,000	19,000	16,000	6,300	70,0
Non-irrigating season					10,2
Annual					80,2

The canal system is designed for a duty of one second foot t acres at diversion, and one second-foot to 100 acres, at land. location of the main canal is shown on Sheets No. 31, 32 and 3 dotted lines.

Diversion. For this West Side Unit there are two possible po of diversion. If the North Unit is constructed as proposed, the di sion for the West Side Unit would be at the Aubrey Falls dam in conjunction with diversion for the North Unit. Should, howe diversion for the North Unit be abandoned at this point, the economical diversion for the West Side Unit alone would be fro point just above Laidlaw, where a low diversion weir will serve canal, located as above for diversion from the Aubrey Falls site. canal from the Laidlaw diversion will take out on the east sid the river and cross to the west side just above the proposed Au Falls dam site. In case the Aubrey Falls diversion is used, the co the dam will be distributed to the North Unit and West Side Un proportion to the volume of water diverted to each.

Notwithstanding the broken and isolated character of the ir ble lands, the cost per acre of constructing the irrigation works this unit is found to be much cheaper than that for either the N or South Units.

If this unit alone is constructed, storage, if required, will be economically obtained in Crane Prairie Reservoir, while if constru in conjunction with either one or both of the other units, storage be provided in Benham Falls Reservoir or both reservoirs combi

Smaller West Side Unit—Bulletin No. 2. During the progres these investigations, it appeared desirable to issue an advance re upon an independent West Side Unit, to cover approximately 1 acres; these lands are included in the area considered in the la West Side Unit herein proposed, and their lesser area is due to omission of lands now under the Squaw Creek Irrigation Compa system which are here added in. The advance report was issue Bulletin No. 2 of the Oregon Co-operative Work and, omitting introduction, is as follows:

Description: The investigations and surveys for a West Side Unit have co the territory from the present State Tumalo Project west to the town of S and north practically to the Metolius River, including what is locally know the Low Desert.

It is found impracticable to serve lands north of Squaw Creek by dive from Deschutes River and it is apparently inadvisable to include lands now ered with yellow pine in the vicinity of Sisters, at the probable cost of cons tion.

The project herein proposed, as a West Side Unit of the ultimate develop of the basin, is shown on map herewith, the shaded portion being the areas co to lands about the summit of the divide between Deschutes and Klamath bas storage in Paulina Lakes and irrigation of lands along Paulina Creek; and a di sion immediately below Cline Falls to cover a few hundred acres in the vici of Odin Falls.

The construction of any or all of these minor projects would have comparati little effect on the question of water supply for the West Side Unit.

The Odin Falls Company owns less than 600 acres, and if they should elect t serve all of their lands from the West Side Unit it would only affect the pr to that extent.

Benham Falls Carey Act Segregation: The Central Oregon Irrigation Com is under contract with the State of Oregon to construct a storage and canal sy for what has generally been referred to as the Benham Falls segregation, l south and east of their present Central Oregon canal unit. The plan prop storage at Crane Prairie for this land.

The contract between the Central Oregon Irrigation Company and the S for the development of this so-called Benham Falls segregation project, inv construction of a dam for storage at Crane Prairie and main canal from nea head of Lava Island in the Deschutes River some 50 or 60 miles, and distribu system for from 50,000 to 60,000 acres. The contract between the Company the State expires in October, 1915. No actual construction work has been done has right-of-way been obtained from the United States for the Crane Prairie r voir site. It is generally understood that the Company has entirely given up intention of developing the project, and it is also evident that it could not be pleted, if fully financed and taken up at once, before the expiration of the con with the State. The construction of the West Side Unit, with Crane Pr storage as proposed, would not be feasible if the Benham Falls segregation pr is constructed.

There is no reason, however, to anticipate any claim, even, of intention o part of the Company to construct the Benham Falls segregation project. Sh they do so, the granting by the United States of right-of-way for stora Crane Prairie would be a matter in which the relative merits of the two pro would undoubtedly be considered, with the probability that Crane Prairie st would be held for the West Side Unit because insufficient for the Benham segregation.

Existing power projects affecting proposed West Side Unit: A small powe velopment at Cline Falls by the Deschutes Power Company has probably acq a right to as much as 200 second-feet flow. The amount to which this dev ment is entitled is uncertain, but however much it may be, the full develop of projects already initiated will require its purchase or condemnation be cheaper than storage for the same amount. It will be several years in any before the river will be drawn upon to an extent which will affect this right in order not to raise the question so far as this proposed West Side Unit is cerned, provision is made in the estimate for storage at Crane Prairie of th amount of water required for the completed project.

The Bend Power and Light Company has an installation at Bend of one w. unit, and power house provision for a second unit. Excavation already and forebay construction contemplate extension of power house to provid two additional units when desired. The rights for this plant would be aff by diversions for irrigation through the Central Oregon Canal and the A Ditch above Bend. The area of land which will ultimately be served by thes diversions is uncertain, but is generally considered as about 45,000 acres. diversion duties already assumed for these canal systems, the maximum dive would be about 900 second-feet. The present high seepage losses may be re to such an extent as not to require a maximum diversion of as much as 600 se feet. The mean summer discharge of the river above these diversions is 1,550 seond-feet. There remains for the power plant, then, under the most fa ble assumption but about 1,000 second-feet. It is not probable, therefore, tha plant would ever be built for much if any in excess of this amount of w The mean winter discharge of the river is over 1,500 second-feet with but r discharges as low as 1,000 second-feet, and these for but a few days during a wave. It is apparent, therefore, that at only infrequent intervals and then fo a few days would the storage of the entire discharge of West Fork at C Prairie during the winter months—generally from 200 to 400 second-feet— fere with the requirements of the Bend Power plant. Since the total dive requirement for the West Side Unit proposed is but 54,000 acre-feet, the a storage required probably less than 40,000 acre-feet, and the estimated mean off from Crane Prairie during the non-irrigating period 110,000 acre-feet.

evident that the requirements of the Bend power plant cannot interfere with the West Side Unit development proposed.

An undeveloped power right is claimed at Pringle Falls on the West Fork of Deschutes River below Crane Prairie. The lack of a market for power will doubtless make it impossible for any of the old water power filings, on which no construction work has been done, to secure conflicting vested rights, in view of the fact that it will be many years before Crane Prairie storage will be required. However, storage of the relatively small amount required for this West Side Unit and diversion during the summer months would doubtless prove a benefit to power development.

Soils and Crops: The soils of this West Side Unit are generally much deeper than on the east side of the river, being wind-blown and frequently alluvial deposits in the depressions between the rimrock tables and buttes. While the hardier fruits might be successfully grown, forage crops with oats, rye, barley and perhaps wheat as the grains, must be looked to as the basis of probable development. There is a possibility that truck gardening can be carried on more successfully, within the area considered, than on the higher lands of the State Tumalo Project and projects on the east side of the river.

Water Duty: A water use of 2.2 acre-feet per acre during an irrigation season, measured at the land, has been assumed for the purpose of the plans and estimates proposed and submitted herewith. While experience may demonstrate this use is excessive, it is by no means an exceptional one, and has been adopted in these plans and estimates in order that the cost of the project may not be under-estimated. The assumed monthly uses in acre-feet per acre are as follows:

May	June	July	Aug.	Sept.	Total
0.4	0.5	0.6	0.5	0.2	2.2

Seepage Losses in Canals. Seepage losses in Central Oregon and Pilot Butte canals, both unlined canals in earth and rock and with a large proportion of shallow irregular canal sections, on the east side of the river, amount to as much as 50 per cent of the amount diverted, or greater.

The plans for the West Side Unit provide for concrete lining for much of the main canal system and it is not believed seepage losses will be proportionately as great as on the east side. Moreover the relative amount of main canal for the West Side Unit is less because of the smaller area to be served from the one diversion.

The seepage losses provided for in this estimate have been derived from different assumed losses for different tracts, depending on the character of the soil, and amount, for the whole project, to a little over 36 per cent cent of the total quantity diverted. Assuming the same proportion of loss throughout the season, the diversion uses in acre-feet per acre by months will be as follows:

May	June	July	Aug.	Sept.	Total
0.63	0.78	0.95	0.78	0.31	3.45

Water Required and Available. Under "Existing irrigation projects from Deschutes River" a total of 145,000 irrigable acres was given. This includes the North Canal of the Central Oregon Irrigation Company, for which the diversion dam and about 1½ miles only of main canal have been completed, but of which no land has been irrigated except about 2,000 acres, under a lateral of the Central Oregon canal, and the project of the DesChutes Land Company south of Benham Falls, which has built a number of miles of main canal, but which has a comparatively small amount of land under irrigation.

If a final average use of water on land for these projects, with the exception of that of the DesChutes Land Company, approximately 30,000 acres, be assumed at the same as that for the West Side Project, and in addition canal losses of 45 per cent of the quantity diverted for these projects, the water requirements at diversion in acre-feet by months will be as follows:

May	June	July	Aug.	Sept.	Total
83,600	104,500	125,500	104,500	41,900	460,000

This is a diversion duty of 4 acre-feet per acre. For the DesChutes Land Company Project south of Benham Falls, it is not believed so large a rate of diversion can be utilized or, if made, that the water can be withheld from the stream, because of the porous nature of the lands and their nearness to the river channel, both of which will induce rapid return flows to the river. Considering this probable return seepage, an assumed net use for the DesChutes Land Company Project, not returned to the projects below, of one-half that for the lower projects, would seem reasonable. On this basis the use on th Chutes Land Company Project in acre-feet by months will be as follows:

May	June	July	Aug.	Sept.	Tota
10,800	13,700	16,300	13,700	5,500	60,00

And the total of all projects diverting above the West Side Unit wi

May	June	July	Aug.	Sept.	Tota
94,400	118,200	141,800	118,200	47,400	520,00

Deschutes River discharge in acre-feet for these months is as follows:

	May	June	July	Aug.	Sept.
Mean	121,000	114,000	105,200	97,600	92,600
Minimum	103,000	102,000	92,300	84,800	81,800

The requirements of the West Side Unit in acre-feet per month wi diversion duties assumed under "Water Duty," will be as follows:

May	June	July	Aug.	Sept.	Tota
9,850	12,200	14,850	12,200	4,900	54,00

It is seen, therefore, that during the month of May of a mean year will be available for use directly from the river, after other projects hav supplied, more than sufficient water for the West Side Unit; that duri succeeding months of June, July and August there would be a deficie 39,250 acre-feet, and that in September again there will be an ample supp the year of minimum discharge for May there would have been a defi for the West Side Unit of but 1,250 acre-feet, but this is the only y record in which there would have been a deficiency in this month.

It is seen that during the months of June, July and August, on the a tions of water uses made, there will be a deficiency in water supply for ing projects which will amount to as much as 37,000 acre-feet for the mo July of a mean year and approximately 50,000 acre-feet for the minimu discharge of record.

For these months, therefore, stored water must be provided for the Side Unit. It is not believed, however, that expensive storage to p against so small a deficiency as would have occurred with the minimu charge of record for the month of May, will be justified. If, therefor extreme minimum for the month of May is not provided for, storage r ments for the West Side Unit proposed will be limited to the months of July and August which, measured at the diversion, have been seen to a to 39,250 acre-feet, called in round numbers 40,000 acre-feet. Followin tabulation of water supply requirements. Quantities given are in acre-fe

	May.	June.	July.	Aug.	Sept.
Water requirements, exclusive of DesChutes Land Co.......	83,600	104,500	125,000	104,500	41,900
Requirement by DesChutes Land Co.	10,800	13,700	16,300	13,700	5,500
Total uses by all projects diverting above West Side Unit	94,400	118,200	141,800	118,200	47,400
River discharge—					
Mean	121,000	114,000	105,200	97,600	92,600
Minimum	103,000	102,000	92,300	84,800	81,800
Requirements West Side Unit	9,850	12,200	14,850	12,200	4,900

Storage Sites. Benham Falls and Crane Prairie reservoir sites, without tion, offer the cheapest storage available. Investigations during the past show Crane Prairie storage to be somewhat cheaper than Benham Falls s largely because the area within Crane Prairie site is all, or nearly a patented land and therefore available for storage purposes on proper sho the Federal Government.

It has been seen that a net storage of about 40,000 acre-feet will be required for the West Side Unit during the months of June, July and August. The available runoff in acre-feet by months at Crane Prairie from October 1, 1913, to April 30, 1914, are as follows:

Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	Total
22,500	19,400	18,750	17,610	13,890	16,800	16,800	125,750

During that year the entire West Fork of Deschutes River gave an excess runoff of 16 per cent over the mean and it is probable that Crane Prairie runoff was similarly in excess so that the mean for the non-irrigation period should be placed at about 110,000 acre-feet.

It is plain, therefore, that there is more than ample supply for the West Side Unit proposed. Economical development of the Deschutes basin as a whole would probably require construction of storage dam for Crane Prairie reservoir to provide for the full amount available for storage. This separate report, however, deals only with the West Side Unit and storage for other than its requirements will not be considered in detail at this time.

Diversion Dam. Investigations of several alternative sites have indicated that the most economical diversion site for the comprehensive development of Deschutes basin as a whole is at a point a short distance above Aubrey Falls and immediately above what is locally known as Little Falls, Section 16, T. 16 S., R. 12 E. Diamond drill borings show a depth of 25 ft. to 30 ft. to bed rock—a dense basalt. Diversion at this site will require the water to be raised approximately 58 ft.

The topographic surveys indicated that for the West Side Unit, considered independently of other future development, a diversion at a point approximately fifteen hundred feet above the old "Swalley Bridge" in Section 20, T. 16 S., R. 12 E., raising the water approximately 34 ft., would require a smaller investment for the West Side Unit alone. Uncompleted diamond drill borings at this latter site show satisfactory foundation at such depth that, considering the cost of extending the main canal up to it, it is doubtful if it will prove to materially lessen the investment required, if any.

The plans and estimates herewith are on the basis of diversion at Aubrey Falls site, test borings for which have been completed, with alternative diversion at Laidlaw.

Status of Lands Under Project. Of the irrigable area within the project approximately one-third is patented, and of the remainder nearly one-half has been filed upon by homestead and desert land entries.

Approximately 4,300 acres is within the segregation for the State Tumalo Project, but not within the limits of that project as now constructed. It will, therefore, with the exception of possibly a few hundred acres, be available for this West Side Unit. About 1,400 acres within the project is land on which no filings of any kind have been made.

The following is a tabulation of these several classes of land with reference to title:

		Acres.
Withdrawn for Tumalo Project but available for this project		4,300
Unpatented lands not filed upon		1,400
Unpatented lands filed upon generally as homesteads and desert land entries		1,540
Patented lands—		
Oregon and Western Colonization Co.	400	
Cline Falls Power Co.	560	
Odin Falls Irrigation & Power Co.	480	
Other smaller owners, total	3,950—	5,390
Total		15,630

Canal Capacities. Since the maximum rate of use determines the capacity of a canal system, the maximum use of water expressed in cubic feet per second is necessary in designing the canal system and preparing the estimates. As has been stated, the maximum use of water for this Unit has been taken as 0.6 acre-feet per acre delivered uniformly through the month of July, or the equivalent of approximately 1 second-foot to 100 acres, measured at the land. The maximum diversion duty for this unit, with the assumed canal losses, is approximately 1 second-foot to 65 acres.

Domestic Use. Some of the lands under the unit will require water th
the canal system for domestic supply during the non-irrigating period as
as during the irrigating period. It has been assumed that the equivale
0.5 acre-feet per acre measured at diversion point will be sufficient.
evident that, in neither the canal capacity required nor in the supply d
the non-irrigating season, will this question enter, for the canal system is
times larger than required for such supply and it is evident that the st
contemplated is but a very small portion of the river discharge durin
non-irrigating season of the year.

State Tumalo Project Extension. There has been suggested the possi
of extending the State Tumalo Project to cover certain areas north o
present State project. Project Engineer O. Laurgaard was requested to
pose any such extension which, from his knowledge of the situation,
appear most attractive. He consented to do this, and was authorized to e
computers to assist him in preparing an estimate which, together with hi
posal, was submitted under date of May 12, 1914.

Briefly, the extension of the Tumalo Project proposed involves the en
ment of feed canal from Tumalo Creek to Tumalo reservoir, increase of st
capacity in Tumalo reservoir by raising both Tumalo and Bull Creek
enlargement of main canal northeast from Tumalo reservoir to Cline Butte
construction of laterals to cover approximately 10,500 acres of the sou
part of the West Side Unit, as shown on accompanying map.

Extracts from Mr. Laurgaard's report, together with estimated cost
conclusions, follow:

"From a Hydrographic study of the flow of Tumalo Creek, it is found tha
irrigation year from October 15, 1910, to October 15, 1911, is a low year, with
off of about 78,000 acre feet. This flow, however, is at the gauging station
all diversions of Tumalo Creek. The new diversion of the feed canal is nine
below the old gauging station and from practically simultaneous readings o
creek, it has been estimated that an additional ten square miles of drainage
will increase the flow of Tumalo Creek about 3,627 acre feet. In addition to
the State of Oregon this season expects to divert Crater Creek and Little
Creek with several springs which have their source from a glacier near the
Broken Top Mountain, from their natural drainage basin into the Tumalo
From a preliminary study made in 1911 the estimated flow of these creek
springs would be about 13,200 acre feet. Bull Creek spring flows between on
two cubic feet per second continuously into the reservoir, which would supply
average about 1,000 acre feet per annum. The estimated annual rainfall o
reservoir area would be about 1,000 acre feet. The annual run-off from the
age area of Tumalo reservoir, which is about 25 square miles, is problematica
no definite knowledge at hand, but in this report it will be assumed that thi
off, which in some years would be considerable, would just offset any po
seepage loss from the reservoir. Therefore, the total amount of water supply
able for the Project during the lowest year on record for nine years from 1
1913, inclusive, is as follows:

Acr
Tumalo Creek at gauging station......................
Estimated increase at diversion point......................
Estimated flow of Crater Creek......................
Rainfall on reservoir area......................
Flow of Bull Creek Spring......................

Total water supply available......................

Against this water supply available, there would occur the following losse

Acr
Losses due to limited capacity of feed canal, overflow of Tumalo Creek......
Seepage losses from the feed canal, which will be estimated at 1 per cent per
mile for the earth portion of the canal......................
(The indications are that these seepage losses will be less than this estimate.)
Losses through interference with ice during the winter season, from Broken
Top diversion ....
Through interference with ice on Tumalo Feed Canal......................
By seepage losses from Wimer Canal......................
By evaporation from the reservoir ....
By seepage losses for 12,000 acres to be irrigated above the reservoir, after
seepage losses have been deducted for the feed canal and Wimer canal; 2
per cent of 1.8 acre feet to be delivered net ....
Losses for 10,500 acres to be irrigated from the reservoir, computed at 25 per
cent of the net delivery at 1.8 acre-feet for the season......................
Losses for 10,500 acres distribution system for the Tumalo Extension, at 3
per cent of the net delivery of 1.67 acre feet per acre......................
Seepage losses from the outlet of the reservoir to the beginning of the irrigable land of the Tumalo Extension unit, which has been computed on a basis
of 1 ft. loss of the wetted perimeter of the canal per day for 100 days irrigating season, on the total length of the canal of 549 stations..........

Total losses ....

"The requirements for irrigation according to the estimates as worked out on the Tumalo Project, net on the ground, would be 22,500 acres at 1.8 acre feet, or 40,500 acre feet. The amounts required for the Tumalo Extension as estimated on the co-operative work is 10,500 acres at 1.67 acre feet, or 17,500 acre feet, making a total of 58,000 acre feet, required for irrigation purposes, net on the ground."

"The amount required for irrigation purposes and the total estimated losses would indicate that 94,831 acre feet would have to be available for a complete irrigation of 33,000 acres. It is found, however, that the total amount available from all sources is only 96,827 acre feet, leaving only a surplus of 1,996 acre feet. However, it is believed that the foregoing estimates are very conservative, especially on the losses from interference through ice, and seepage losses on the feed canal and our main canal from the reservoir. Also no addition has been made for the inflow into the reservoir from the 25 square miles of drainage area which, from best knowledge, we know at some seasons is considerable, but neither have we considered any seepage losses from the reservoir which may be of some consequence, although indications at the present time are that the reservoir will be tight."

"In view of the above, it would not be policy to consider the actual irrigation of 10,500 acres additional from Tumalo Creek, until the seepage losses from the reservoir and the present feed canal are determined with some degree of certainty, and until the flow of Crater Creek can be ascertained by measurements for at least one season, to determine the amount that could be utilized."

"Should it be determined that the water supply is sufficient to irrigate 10,500 acres additional, it will be necessary to increase the capacity of the Tumalo Feed Canal from 225 cu. feet per second to 350 cu. feet per second. The capacity of the reservoir would also have to be increased from 20,000 acre feet to 32,000 acre feet. With a capacity of 350 cu. feet per second for the feed canal we could divert all of the Tumalo Creek flow, except 608 acre feet and a portion of this could also be obtained from the old Columbia Southern Canal and Wimer Canal, both of which are now owned by the State of Oregon. In order to obtain a capacity of 32,000 acre feet for Tumalo Reservoir, it will be necessary to reconstruct Bull Creek Dam, which will also serve as spillway for the reservoir, and raise it some ten feet in elevation, or from 3,511 to 3,521. It will also be necessary to raise Tumalo Dam ten feet in elevation, from 3,518 to 3,528. This report will include an estimate for the enlargement of Tumalo Feed Canal, reconstruction of Bull Creek and Tumalo Dams, the enlargement of Tumalo Main Canal from the reservoir, and the construction of a new canal around Cline Buttes to Dry Canyon."

Summary: The estimated cost of irrigating 10,500 acres in the Tumalo Extension Project by the enlargement of the Tumalo Feed Canal, Tumalo Reservoir, Tumalo Main Canal and the construction of the Main Canal of the Tumalo Extension may be summarized as follows:

Land Damages	$ 14,625
Feed Canal	67,064
Bull Creek Dam	15,111
Tumalo Dam	37,140
Main Canal	80,045
Main Canal, Lateral "A"	46,180
Main Canal, Tumalo Extension	79,437
Distributing System, 10,500 acres @ $8.00	84,000
Total	$423,602
Engineering, Contingencies, Insurance, Incidentals, etc., 15 per cent	63,540
Total	$487,142

Estimated cost per acre for 10,500 acres, $46.40.

Conclusion. "The lands under the Tumalo Extension Project are very suitable for the raising of forage crops, dairying and stock raising. Among some of the principal crops that may be raised are alfalfa, clover and vegetables. On account of the actual short growing season and the cold nights, it has been the practice up to the present time to cut only two crops of alfalfa and clover, pasturing the third, but it is believed that after large areas, under a Project such as the Tumalo and Tumalo Extension, have been cleared of sage brush and juniper trees, the frost conditions will be materially improved and that eventually three crops of clover and alfalfa may be harvested. There have been three crops cut on special occasions by various farmers in the vicinity. With the limited amount of lands in the Central Oregon country adapted to irrigation and considering the very high price that hay and forage crops command in this vicinity continuously, it is believed that the price as estimated of $46.40 per acre is not excessive and that the lands are good security for that amount, especially should the first payment be very small and the deferred payments be carried over a period of say 15 to 20 years without interest, as is the custom with Government projects."

"Although all of the canals have not been actually located for this estimate, the ground has been rather thoroughly covered to obtain a reliable estimate. The unit prices used are not excessive but it is believed are liberal and the work should be done for the estimated price."

"In view of the close relation between the amount of water supply available for the Tumalo Extension Project and the amount that will be required, it would not be good policy to consider the actual construction of the Tumalo Extension Project at this time, before the actual losses from the Tumalo Reservoir have been determined with some degree of certainty, and until the actual amount of water that may be supplied from Crater and Little Crater Creeks may be measured; especially as the Tumalo Reservoir will be completed about Oct. 1, 1914, and the waters of Crater and Little Crater Creeks determined and diverted before that time."

At the time the possibility of an extension to the Tumalo Project was cussed by Mr. Laurgaard and the estimate prepared, a water use of 1.67 feet per acre, measured at the land, had been tentatively assumed, and per cent loss in the distributing system.

Water requirements for the West Side Project subsequently agreed for the Oregon Co-operative Work investigations, was fixed at 2.2 acre-feet acre, and a further domestic use during the non-irrigating period of 0.3 feet per acre, measured at the land.

The 30 per cent loss in the distributing system was also figured as 30 cent of the gross amount delivered to the canals and not of the net am delivered at land.

The loss in distributing systems under these assumptions, for the area posed by Mr. Laurgaard, would therefore be 11,250 acre-feet.

The seepage losses from the outlet of reservoir to beginning of irrigable of the extension, would also be somewhat larger. The actual amount of required to be delivered, under the water use assumed subsequent to the p ration of Mr. Laurgaard's estimates, would be increased from 17,500 acre to 26,250 acre-feet.

The evaporation from reservoir on account of increased storage requ would also be somewhat increased. On these assumptions, therefore, th creased amount of water required would be not less than 16,000 acre-feet, the total amount of water required for Tumalo Project under the water adopted for that project, together with the proposed extension and the use assumptions made by the Oregon Co-operative Work investigations, woul not less than 111,000 acre-feet. Mr. Laurgaard states that the total am available from all sources, including certain proposed and uncertain incr from Crater Creek, would be but approximately 96,800 acre-feet.

If the additional supply assumed to be required were available, the incr cost of feed canal, Tumalo and Bull Creek dams, would probably be bet $40,000 and $50,000, but if it is called $40,000, and the estimate for engi ing, administration, and contingencies increased from 15 per cent to 25 cent, as in the Oregon Co-operative Work estimates, the total cost for Tumalo Project Extension proposed would be $579,500, or approximately $ per acre.

Estimated Cost of Proposed West Side Unit. The area proposed for this Side Unit is 15,630 acres. The estimated cost is for storage, diversion da Aubrey Falls, with alternative diversion at Laidlaw, main canal to distrib laterals, and distributing system.

A net stored supply of approximately 40,000 acre-feet is shown to be requ

The physical conditions at Crane Prairie dam site are such that the cons tion of a dam to store as much as 55,000 acre-feet, will cost very little than construction to store 40,000 or 50,000 acre-feet. For this reason, an order to provide for evaporation and possible seepage losses, it is propose construct Crane Prairie dam to raise the water 17.0 ft. and thus provi storage capacity of 55,000 acre-feet.

The design on which this estimate is made is such that whenever it ma required in the future the structure may be increased at minimum cost. increase of approximately 9.5 ft. in height of dam will provide storage fo mean estimated run-off of 110,000 acre-feet available during the non-irrig season.

Following is estimated cost of completed project for 15,630 acres, indepen of other development:

Crane Prairie Dam.

avation—					
Earth stripping	2,000	cu. yds.	@ $ .25	$ 500	
Rock, outlet channel	7,300	" "	@ 1.50	10,950	
" spillway	2,000	" "	@ 1.25	2,500	
Concrete lining, outlet channel	220	" "	@ 12.25	2,695	
crete in structures—					
Outlet gates 470					
Cut-off walk 5					
Spillway 75—	550	" "	@ 14.50	7,975	
Steel re-enforcement	2,000	lbs.	@ .06	120	
bankment—					
Earth haul (from spillway)	5,500	cu. yds.	@ .25	1,375	
" " (½ mile borrow)	10,500	" "	@ .50	5,250	
" rolling	12,700	" "	@ .20	2,540	
Rock haul (from outlet)	9,600	" "	@ .50	4,800	
" " (from spillway)	2,600	" "	@ .25	650	
Riprap (hand placed)	1,800	" "	@ 2.50	4,500	
cellaneous—					
Cofferdam trestles, 2 at $200				400	
Roads, 5 miles at $500				2,500	
One 120 ft. trestle bridge				400	
Three temporary buildings at $500				1,500	
One keeper's house				2,000	
Twenty miles telephone line to La Pine at $100				2,000	
Stop logs, hoists, etc.				1,745	
Total				$ 54,400	
inistration, engineering and contingencies, 25 per cent				13,600	
Total					$ 68,000

Aubrey Falls Diversion Dam.

porary Diversion—					
Canal excavation	8,000	cu. yds.	@ $ .50	$ 4,000	
Canal lining concrete	550	" "	@ 8.00	4,400	
Coffer dam				800	
avation for Dam—					
Foundation	10,000	" "	@ 1.50	15,000	
Foundation	5,000	" "	@ 1.00	5,000	
crete in dam	7,000	" "	@ 11.00	77,000	
l re-enforcement	240,000	lbs.	@ .05	12,000	
ds				3,500	
ds				2,000	
keeper's house and stable				2,500	
t Side Unit gates, exclusive of gates proper				600	
th Unit gates, exclusive of gates proper				1,800	
Total				$128,600	
ineering, administration, contingencies, 25 per cent				32,400	
Total					$161,000

Canals, Aubrey Falls Diversion Dam to Heads of Main Laterals:

avation, earth	130,080	cu. yds.	@ $ .25	$ 32,520	
" rock	83,100	" "	@ 1.10	91,410	
crete, structures	600	" "	@ 15.00	9,000	
" canal lining, (1:1 slopes)	4,320	" "	@ 7.50	32,400	
" " " (½:1 slopes)	200	" "	@ 8.75	1,750	
l re-enforcement	60,000	lbs.	@ .05	3,000	
r highway bridges, at $150				600	
e turnouts				420	
teway at Little falls				500	
" " Mile 5.1				560	
" " Mile 11.3				5,340	
verts, 5 at $200				1,000	
phone line, 18 miles at $250				4,500	
e fence (5 wire) 32 miles at $125				4,000	
s and structures at Diversion Weir				900	
ds, improvements and right of way				3,500	
Total				$191,400	
ineering, administration and contingencies, 25 per cent				47,600	
Total					$239,000

Distribution Laterals and Drainage:

average cost of $9.80 per acre served, has been estimated will equired for distribution laterals. Drainage required is indeter- ate, but $1.00 per acre has been allowed in this estimate. h engineering, administration and contingencies charge of 25 cent added, this becomes $13.50 per acre and for 15,630 acres	$211,000
Total	$679,000

Cost per acre for completed project $43.44.

Value of Aubrey Falls Diversion Dam to Other Future Development. Fr the surveys and investigation made of Deschutes basin as a whole, practica completed studies show that a North Unit of approximately 100,000 acres land north of Crooked River can be irrigated by water from Deschutes Ri and that the most economical diversion point is the Aubrey Falls site propo for this West Side Unit.

Discussion of this at length will be made in the general report now bei prepared but, without going into it further at this time, it may be stated t the diversion elevation adopted for the West Side Unit, is well adapted t North Unit diversion.

The amount of water estimated to be required at the diversion for the No Unit is very close to five-sixths of the amount required for both West Side North Units. While the entire cost of the Aubrey Falls diversion is inclu in the estimate herewith for the West Side Unit, five-sixths of its cost, $134, will be a proper charge against the North Unit whenever it is taken up therefore a credit of this amount to the West Side Unit would be made at t time. Such a credit will reduce the actual cost of West Side Unit to $3 per acre.

Alternative Plan With Diversion at Laidlaw. The preceding plan invol construction of the comparatively expensive Aubrey Falls diversion dam. Sho the North Unit, north of Crooked River, be built later, five-sixths of the of Aubrey Falls diversion would properly be charged to the latter Unit noted. Since the construction of the North Unit is by no means assured. advisability of adopting Aubrey Falls diversion is questionable if any ot diversion involving less total investment for West Side Unit is practicable.

A low diversion opposite Laidlaw, with unlined earth canal and metal fl construction on east side of river, crossing to west side about fifteen hund feet above Little Falls, as shown on map, and joining the Aubrey Falls ca location. will provide a plan requiring approximately $32,000 less investm for the entire Unit.

As partly affecting this, will be the higher operating and maintena charge, and the probability that if the Aubrey Falls diversion dam is built, the West Side Unit would be required to absorb a part of its cost, at l to the extent of its estimated worth to the West Side Unit, in reducing op tion and maintenance cost.

he following is estimated cost of construction for Laidlaw diversion alter-
ve:

rane Prairie Dam.

e as for Aubrey Falls Diversion alternative					$ 68,000

aidlaw Diversion Weir.

vation	5,000	cu. yds.	@ $ .60	$ 3,000	
fill and riprap	1,000	" "	@ 2.50	2,500	
rete	200	" "	@ 15.00	3,000	
ber cribbing, deck, etc.	100-M	B. M.	@ 40.00	4,000	
nforcing steel	16,000	lbs.	@ .05	800	
erdams and protective works				1,000	
gate structure, exclusive of gates				2,000	
keeper's house				2,500	
ls, improvements and right of way				2,000	
Total				$ 20,800	
neering, administration and Contingencies, 25 per cent				5,200	
Total					$ 26,000

Main Canal, Laidlaw to Aubrey Falls.

vation, earth	16,000	cu. yds.	@ $0.25	$ 4,000	
" rock	9,700	"	" 1.10	10,670	
rete, canal lining	230	"	" 7.50	1,725	
ft. of No. 180, No. 15 gauge metal flume, including trestle and footing.			" 6.50	55,250	
ghway Bridge				150	
ft. Span Deck Truss Steel Bridge, including trestle approach and abutments				7,200	
niles telephone line			@ $250	875	
" fencing			" 125	250	
t of Way				2,000	
ts sluice gates and hoists				1,350	
				$83,470	
neering, Administration and Contingencies, 25¢				20,530	
Total					$104,000

Main Canal, Aubrey Falls Damsite to heads of Main Laterals.

vation, earth	130,080	cu. yds.	@ $0.25	$ 32,520	
" rock	83,100	"	" 1.10	91,410	
rete, structures	600	"	" 15.00	9,000	
" canal lining (1:1 slope)	4,320	"	" 7.50	32,400	
" " " (½:1 slope)	200	"	" 8.75	1,750	
reinforcement	60,000	lbs.	" .05	3,000	
ghway Bridges, @ $150				600	
rnouts				420	
eway at Little Falls				500	
" " Mile 5.1				560	
" " " 11.3				5,340	
erts, 5 @ $200				1,000	
hone line, 18 miles @ $250				4,500	
fence (5 wire), 32 miles @ $125				4,000	
s, improvements and right of way				3,500	
				$190,500	
neering, Administration and Contingencies, 25¢				47,500	
Total					$238,000

Distribution laterals and drainage.

as for Aubrey Falls Diversion alternative					211,000
Total					$647,000

per acre for completed project, $41.40.

ssible Smaller Developments. Present and prospective developments of
active projects in the Deschutes basin, indicate very clearly that a great
years may elapse before the use of water reaches a point where the
hutes River flow will need to be supplemented by storage for this unit.
e, therefore, estimates should cover the future possible necessity of build-
the Crane Prairie reservoir, for the purpose of determining the amount of
nt investment required, the storage provision may be omitted.

ccessive developments of the project would logically be for: First, about
acres; second, approximately 4,400 acres more; third, completion of dis-
ting system for entire project, and finally the Crane Prairie storage.

Estimated investment, for these successive developments are as follows:

Aubrey Falls Diversion Alternative.

First Development.

For 6,600 acres—

Aubrey Falls Diversion	$161,000	
Main Canal to Mile 14.3, omitting wasteway at Mile 11.3, fencing, turnouts, and all construction not essential to the irrigation of this area	204,000	
Distributing laterals for this area only and omitting drainage allowance	80,850	
		$445.

Second Development.

For a total of 11,000 acres—

Additional for distributing laterals	53,90
Additional for Main Canal	35,00
	$534.75

Third Development.

For the total area of 15,630 acres—

Additional for distributing laterals, including drainage	76.25
	$611,0

Fourth and Final Development.

For completed project—

Crane Prairie storage	69
Total	$67

Laidlaw Diversion Alternative.

First Development.

For 6,600 acres—

Laidlaw Diversion Weir	$ 26,000	
Main Canal	342,000	
Distributing laterals for this area, omitting drainage allowance	80,850	
		$14

Second Development.

For a total of 11,000 acres—

Additional for distributing laterals for this area	53
	$502.

Third Development.

For the total area of 15,630 acres—

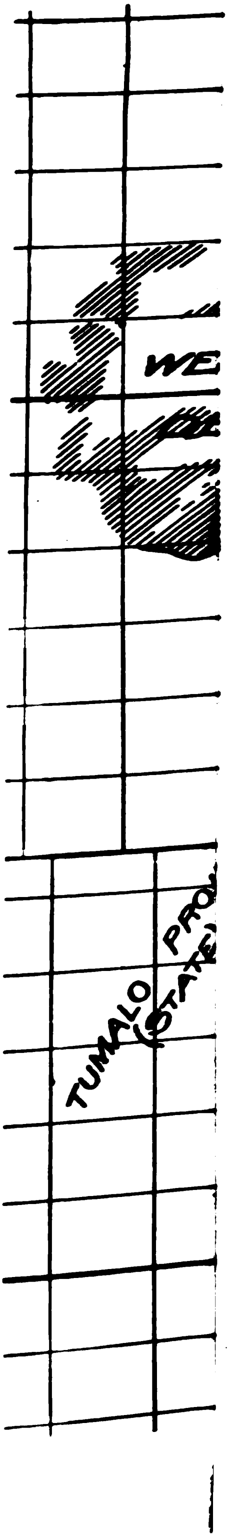
Additional for distributing laterals for this area, including drainage allowance	76.
	$579.

Fourth and Final Development.

Crane Prairie storage	68,0
Total	$647.00

NORTH UNIT.

The proposed North Unit, as finally adopted, covers 99,300 acres of irrigable land. The irrigable areas are shown on Sheets No. 26 to 30, inclusive, by diagonal hatching. It was found impracticable to serve lands to the east of Hay Creek and uneconomical to serve the Hay Creek bottom lands; these areas, therefore, have been excluded. The lands included in this unit are generally as fertile as the best lands in the West Side Unit; moreover, due to their somewhat lower elevation and greater distance from the Cascade Mountains, they are in a measure more free from summer frosts which occur in the region covered by the other units lying south of Crooked River. The extreme northeastern portion of this proposed North Unit is very rolling.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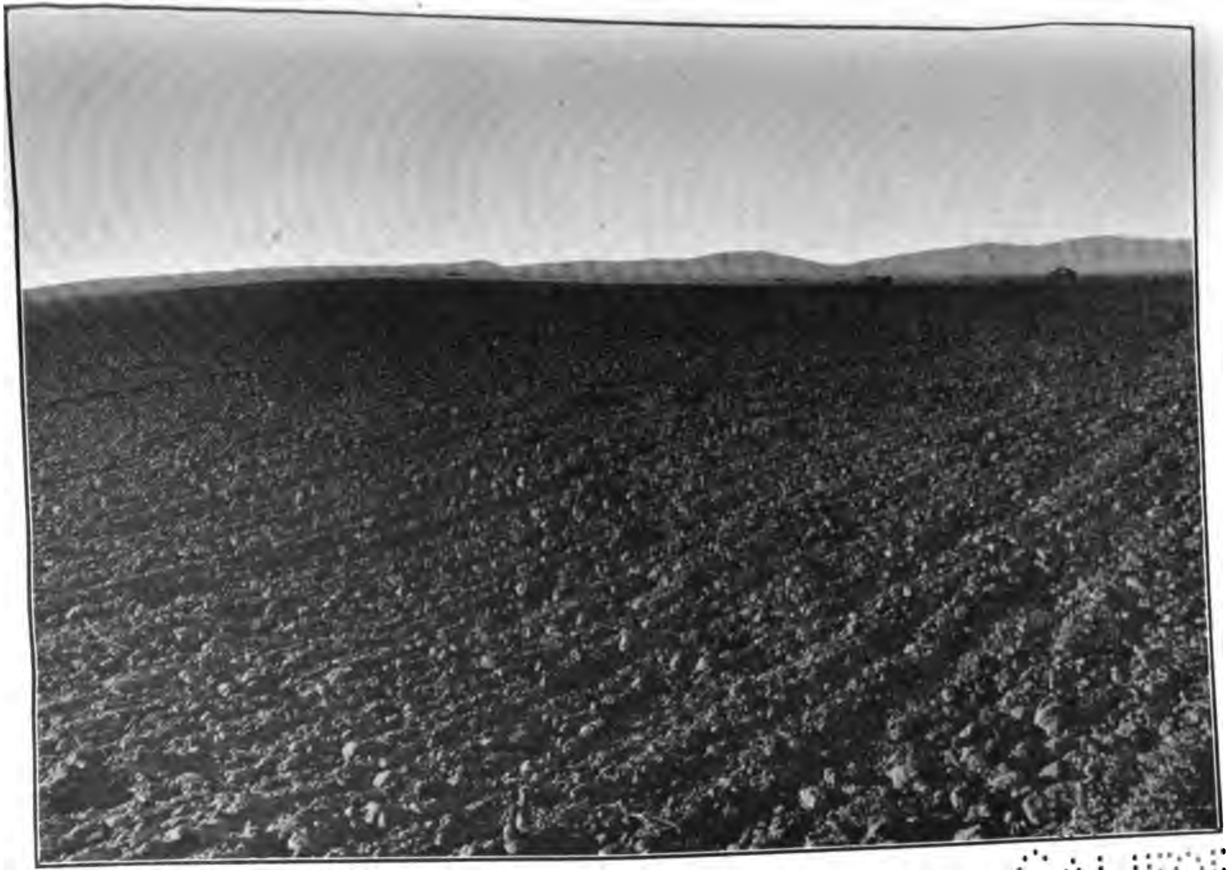

Agency Plains looking Northwest from Point about One Mile North of O. W. R. & N. Depot.

Plate XII.

This unit has the great advantage that two railroad lines extend practically its entire length.

Water Required. The assumed monthly use of water for the North Unit during the irrigating season, measured at the land, and expressed in feet of depth, is as follows:

May	June	July	Aug.	Sept.	Total
0.3	0.5	0.6	0.4	0.2	2.0

Seepage losses in distribution laterals have been placed at 25 per cent of the water delivered at their heads.

These losses are low, owing to the fact that the slope of the land is generally so great that concrete lined laterals have been planned, as being more economical to build and maintain than unlined channels. Seepage loss in the main canals is estimated at one inch in depth per day over wetted area. All main canals are proposed to be concrete lined.

The resulting assumed monthly diversion requirements per acre are as follows, expressed in acre-feet:

May	June	July	Aug.	Sept.	Total
.405	.675	.81	.54	.27	2.70

For domestic and stock use during the non-irrigating season, an allowance of 0.5 of a foot in depth per acre, measured at the point of diversion, has been allowed for this unit, this being equivalent to a continuous diversion of about 120 second-feet. Probably this allowance is entirely too large; with concrete canals, a continuous flow of only a small portion of this quantity will be sufficient to supply all requirements and keep the channels sanitary by flushing. The quantity is clearly on the safe side.

The total assumed diversion requirements for the North Unit for the year, expressed in acre-feet, is as follows:

May	June	July	Aug.	Sept.	Total
40,200	67,000	80,400	53,600	26,800	268,000
Non-irrigating season					49,500
Annual					317,500

As already indicated, any irrigation development with water from Deschutes River below Benham Falls, beyond that required for irrigation works constructed, or under construction, will require storage, if the various Carey Act and other projects holding prior rights to the natural flow proceed to a full development. For purposes of this investigation it is necessary to assume that such will be the case, and that the North Unit must derive the greater part of its irrigation supply from storage works. The canal system is designed for a duty of from one second-foot for 76.5 acres at the diversion to one second-foot for 103.2 acres at the land. The location of main canal is shown on Sheets No. 26, 27, 28 and 30, in heavy dotted lines.

Diversion. The point of diversion determined upon for this unit is the Aubrey Falls diversion site, in conjunction with diversion to the West Side Unit from the same point. Construction of this Aubrey Falls diversion dam contemplates the distribution of the cost to the North Unit and the West Side Unit, in proportion to the volume of water diverted to each.

SOUTH UNIT.

The area to be served by the South Unit, as finally adopted, totals 48,460 acres of irrigable land. The main body of this irrigable land lies east of the Horse Ridge lava beds and the Dry River Bed, and approximately 30 miles from Deschutes River. The irrigable areas are shown on Sheets No. 34, 35, 36 and 37, by hatching.

In the past, the irrigable area which could be served by the main canal system contemplated in this unit, had been said to amount to about 75,000 acres. However, the high cost of constructing the irrigation works, considering the climatic conditions and the character of the soils existing over the district comprised in this South Unit made it necessary to eliminate from the unit, all lands which tended to increase the acre cost of construction. Pursuant to this decision areas to the north of Powell Buttes and south of the main high line canal at its eastern end were eliminated, the former owing to the character of the lands and the cost of serving, the latter owing to the cost of holding up the grade of the main canal in order to serve the same. Some of the lands about Powell Buttes and Horse Ridge or Bear Buttes are very fertile and, so far as economical, have been included in this unit.

West of Horse Ridge lava beds are some 6,000 to 7,000 acres of land to be served, which are very similar to those found in the region immediately north and served by the Central Oregon Canal.

The Dry River Bed, after cutting through Horse Ridge in a canyon several hundred feet deep, immediately opens out and forms a broad bottom without any distinct boundaries or shore line until Powell Buttes are reached, where it again enters a canyon. This bottom between these two canyons appears to have a sandy soil and it is probable that a relatively large amount of water will be required to irrigate it. No wells exist in this region. A prospective well at the mouth of the Dry River Bed canyon through Horse Ridge which was sunk to a depth of 100 feet, did not reach water or bed rock.

Water Requirement. The assumed monthly use of water for the South Unit, during the irrigating season, measured at the land and expressed in feet of depth, is as follows:

May	June	July	Aug.	Sept.	Total
0.3	0.6	0.6	0.6	0.4	2.5

Although the climate of this unit is so influenced by elevation and location that the irrigating season is liable to be somewhat

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cent of the water delivered at their heads. Seepage losses in the main canals have been assumed at one foot in depth per day over wetted area, for unlined sections, and one inch in depth per day over wetted area for lined sections.

The resulting assumed monthly diversion requirements are as follows:

May	June	July	Aug.	Sept.	Total
0.470	0.955	0.955	0.955	0.635	3.97

For domestic use during the non-irrigating season, an allowance of 0.5 of a foot in depth per acre, measured at the point of diversion, has been allowed for this unit. The total assumed diversion requirements for the South Unit for the year, expressed in acre-feet, is as follows:

May	June	July	Aug.	Sept.	Total
22,800	46,300	46,300	46,300	30,800	192,500
Non-irrigating season					24,200
Annual					216,700

As already indicated, any irrigation development, with water from Deschutes River below Benham Falls, beyond that required for irrigation works, constructed or under construction, must for present purposes be assumed to require storage, and the greater part of the supply for this South Unit during the irrigation season must be so obtained. The canal system is designed for a duty of one second-foot to 64 acres, at diversion, and one second-foot to 103 acres at land. The location of main canal is shown on Sheets No. 23, 34, 35, 36 and 37, in dotted lines.

Diversion. The point of diversion proposed for this unit is at Lava Island Falls. This location is quite definitely fixed for the reason that, on the one hand any diversion further up the river would require a canal along the lava beds which border the river on the east bank from Lava Island Falls to Benham Falls, while on the other hand any lower diversion point would not command certain controlling passes west of the Dry River Bed.

EAST SIDE UNIT.

The area east of Deschutes River and South of Crooked River to the Central Oregon Canal may be considered as an East Side Unit, although as planned by the Central Oregon Irrigation Company, which has already constructed canals to cover the larger part of this area. it will be served from two diversions; the present Central Oregon diversion and canal, now completed, and the North Canal dam and main canal, still incomplete.

It has been claimed that water could be carried from the Pil Butte canal, owned by the Central Oregon Irrigation Company, dow the peninsula between Deschutes River and Crooked River, to cov an area variously estimated at from 6,000 to 10,000 acres. Survey which developed topography additional to that available from th Central Oregon Irrigation Company's surveys, showed that thes lands could only be reached by an impracticably long and expensiv pipe line, owing to the fact that the elevation of the connecting lan between the Pilot Butte Canal and the peninsula is too low to us a canal.

In view of the uncompleted condition of this North Canal, con parative estimates of cost were made between the Aubrey Falls d version, with canal to Crooked River crossing, and a diversion a North Canal dam, by enlarging the portion of canal at present con structed, with continuation of the same to Crooked River crossin

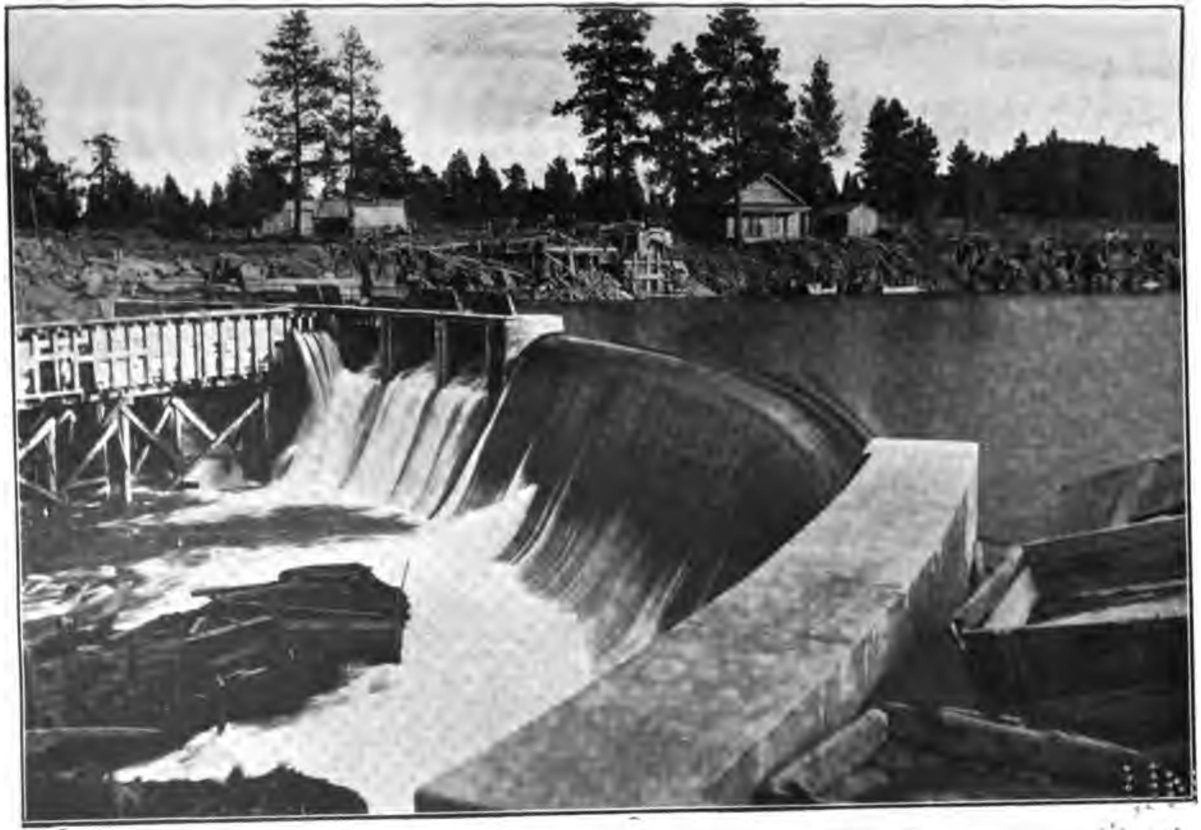
The length of line from North Canal Dam to Crooked River cros ing is approximately 26 miles, while from Aubrey Falls it is but 18. miles. Taking the North Canal dam and canal as it stands, it is est mated that to enlarge the canal to the capacity necessary for servin the North Unit, the Pilot Butte and Central Oregon systems as pro posed by the company, and continuing it to to the Smith's Roc crossing of Crooked River, will cost, exclusive of any amount whic might be paid the Central Oregon Irrigation Company, not less tha $1,100,000, while the cost of a system delivering an equal amoun of water from Aubrey Falls diversion will be $907,000, including th proportionate part of cost of Aubrey Falls diversion dam.

It appears therefore, that, unless the North Canal be develope to serve the Central Oregon Company's North Canal Unit of betwee 35,000 and 36,000 acres, in conjunction with the delivery of wate for the North Unit at the crossing of Crooked River, it cannot b considered at any price for the North Unit.

EAST SIDE UNIT.

Valuation of North Canal Unit—Central Oregon Irrigation Com pany—Bulletin No. 1. There remains between the Pilot Butte cana system and the Central Oregon Canal system, a net area of some 35. 000 acres of irrigable land, which is known as the North Canal Uni of the Central Oregon Irrigation Company project. The Pilot Butt Canal is served by the North Canal of the North Canal system, whicl is completed from the diversion to a junction with the Pilot Butt Canal.

Tentative proposals have been made that the existing North Cana dam and canal be taken over by the State or the Reclamation Service or both, for a money consideration, with the provision that the Reclamation Service deliver 306 second-feet during the irrigation



NORTH CANAL DIVERSION DAM OF CENTRAL OREGON IRRIGATION CO.

PLATE XIV.

UNIV. OF
CALIFORNIA

season to the Pilot Butte Canal, and 114 second-feet at some point for the Powell Butte lateral of the Central Oregon Canal system.

In conformity with an agreement between the State authorities and the Reclamation Service, an estimate of the value of the property proposed to be turned over was made by Joseph Jacobs, Consulting Engineer, United States Reclamation Service, E. G. Hopson, Supervising Engineer, United States Reclamation Service, and John H. Lewis, State Engineer for Oregon. The estimated valuation and cost of completion, as submitted by this Board, was issued as Bulletin No. 1 of the Oregon Co-operative Work and is as follows, omitting introductory matter covered by this report:

Existing Works. The portions of the North Canal system already completed or partially completed, consist of the headworks on the Deschutes River one mile below the town of Bend, of the main canal from the headworks to the junction with the Pilot Butte Canal, a distance of 1.4 miles, and of laterals for 978 acres of land.

The diversion dam is a concrete masonry structure, curved in plan but of gravity section, and having a maximum height of 40 feet above lowest foundation, an over-all length of 300 feet and a spillway length of 148 feet. In addition to the spillway, it is provided with four wasteway openings, each 12 feet wide, one fishway opening 6 feet wide and one opening 6 feet wide for the Swalley Ditch, all having their sills 6 feet below crest of spillway, and all controlled by wooden flashboards or needles.

The intake for North Canal is also a concrete structure. It is located on the right bank of the river, and is separated from the dam proper by about 35 feet of rock ledge. It is provided with four openings, each 5 feet wide by 7½ feet deep, controlled by steel gates and hand operated screw stands. This intake and the dam, which together constitute the entire headworks, have been completed.

These works are of substantial design and construction, and are ample to meet the purposes they are intended to serve. A criticism that has been made by some, is that the concrete is less dense than would ordinarily be expected in works of this character. The stone and sand required for the concrete were obtained by crushing the native lava rock at the dam site, no river gravel being available, and it appears that the crusher used did not supply a sufficient amount of fine sand, the result being a rather porous concrete that permits some seepage of water through it.

The stability of the present structure is not questioned, but this feature of porosity and resultant seepage through the concrete, might induce the leaching out or dissolution of the cement to an extent sufficient to ultimately weaken the concrete and, as a precaution against such a contingency, may necessitate the treatment of upstream face of dam with some substantial waterproofing process.

The main canal, which has a length of 7,460 feet from intake to Pilot Butte Canal, has been only partially completed. It lies for the most part in heavy rock cutting, and is intended to be concrete lined throughout. The excavation has been about 96 per cent completed, and the concrete lining, which is 4 inches thick, about 33 per cent completed. The finished canal section has a bottom width of 12 feet, side slopes of ¼ to 1, provides for a water depth of 8.25 feet and a carrying capacity at that depth of about 1,050 second feet.

The concrete lining of canal is subject to the same criticism, as to porosity, as that offered with respect to the dam and headworks. It may also be noted that somewhat flatter side slopes than ¼ to 1 would have been better construction, and revision of this feature for the unfinished portions of canal might well be considered, should completion of the project be undertaken by the State and Government. All of this work, i. e., the dam and headworks and portions of main canal, was done during the period March to December, inclusive, of 1912, and they may therefore be regarded as practically new.

Initial Cost of Existing Works. In an estimate of the total cost to April 1, 1914, of the North Canal system, the Central Oregon Irrigation Company sub mits the following tabulation of such total cost, together with details of the makeup of each item, which latter it seems unnecessary to include in this report:

Initial expense of securing segregation	$ 56,318
Dam and headworks	88,061
Main canal, Sta. 0 to Sta. 74+60	85,167
Surveying	11,558
Overhead expense	50,293
Development expense	125,000
Miscellaneous	10.593
Total	$426,990

The difficulties with which private irrigation companies have had to contend during the past decade in the promotion and development of their enterprises are fully appreciated, and neither the accuracy nor legitimacy of the above mentioned expenditures as related to the operation of the Central Oregon Irrigation Company is questioned. No critical analysis of those intangible elements of cost, such as development expense, initial expense of securing segregation, etc., which bulk so large in the above estimate, has been attempted. The following view has been accepted as a basis for this report: However much or little may have been expended in bringing this project to its present status, it appears that the only items that could now be offered for transfer and delivered in the event of purchase, and therefore the only items which can be properly considered, are those physical or tangible elements of property which can actually be used as parts of a completed project.

It is not intended by this that value may not attach to properties by reason of certain intangible elements, as, for instance, franchise rights and development work which has succeeded in bringing a property to the status of a "going concern," or at least of putting it in such condition as to enable it to finance itself and proceed with its construction. Apparently, however, these conditions do not obtain in this case, the only real asset now attaching to the project being these partially completed works, and even these are negotiable only in connection with this particular project.

It is of course proper to allow, in addition to the actual field cost of the physical works, a reasonable charge for overhead expense upon such items, and a reasonable interest on investment during the period of construction. Upon this basis the initial cost of tangible assets has been estimated, as tabulated below, all items included being identical with the items listed in the Company's estimate except that of overhead expense, which has been reduced to apply to constructed works, and also except that of constructed laterals, which apparently were not included as such in the Company's estimate.

Dam and headworks		$ 88,061
Main canal, Sta. 0 to Sta. 74+60		85,167
Surveying—Canal locations and subdividing 11,920 acres into 40-acre tracts	$6,912	
—Topographic mapping of 54,022 acres	4,646—	11,558
Completed laterals for 978 acres @ $4.00 (Estimate)		3,912
Miscellaneous—Undistributed vouchers against dam and main canal	$3,093	
—Interest on investment during construction period	7,500—	10,593
Overhead expense, 10% of above items		19,929
Total		$219,220
Called		220,000

Present Value of Existing Works. To arrive at present value of existing works, the method of determining the cost of reproduction new has been adopted; no deduction has been made for depreciation, for the reason that the works are practically new at this time, and because any assumption as to the slight depreciation which the works may have suffered since completion would be purely theoretical and unwarranted.

The Company's estimates of quantities have been accepted as correct, except in one instance, and its unit costs have also been adopted, these being changed only where they appeared unduly high. In other words, there has been no attempt to scale down the Company's actual costs to a theoretic minimum cost of reproduction, but rather to develop a fairly conservative estimate of reproduction cost based on events that actually transpired. Below are tabulated, for the dam and canal, only those items in which changes from the unit costs or quantities submitted by the Company in their detailed estimate have been made:

Dam and Headworks

	Cost Reduction
Diverting river and taking care of water in foundation excavations (lump sum)	$1,942
Dam excavation between elevations 3560 and 3555 (W. S. at Elev. ±3561), 1129 c.y.	1,772
Dam excavation between elevations 3555 and 3549, 489 c.y.	924
Cyclopean concrete in dam, 5277 c.y.	3,536
Total	$8,174

Estimate for cost of dam and headworks is therefore $88,061 minus $8,174 equals $79,887. Called $80,000.

Main Canal

	Cost Reduction
Rock excavation, 34,632 c.y.	$13,509
Concrete canal lining, 1,252 c.y. per Company's statement and 835 c.y. per this estimate	6,205
Trestle crossing of Oregon Trunk Railway*	478
	$20,192

Estimate of cost for main canal is therefore $85,167 minus $20,192 equals $64,975. Called $65,000.

As the other features of the Company's estimate were accepted without change, the total estimated cost of reproduction new would be as follows:

Dam and headworks	$ 80,000
Main canal, sta. O to sta. 74+60	65,000
Miscellaneous items for dam and canal as covered in the Company's estimate by undistributed vouchers	3,093
Laterals for 978 acres	3,912
Surveying	11,558
Overhead expenses, 10% of above items	16,356
Interest on investment during construction period (½ above amount, 9 mo. @ 6%)	4,048
Total	$183,967
Called	184,000

Existing Land and Water Right Contracts. Among other features of the Company's proposal is that water rights shall be recognized and deliveries made to 2,200 acres of land already sold by the Company. Of these 2,200 acres, 978 acres are now receiving water from the Central Oregon Canal, and the remaining 1,222 acres, which are now dry, could be similarly served if necessary. The lands, however, fall naturally within the North Canal Unit, and should properly be served by it. The proper treatment of such land, in event of purchase of the Company's assets, would be to include it as part of the project, recognizing its water rights, so far as the land owners are concerned, but charging the actual cost of providing water, i. e., the initial cost of irrigation, to the Central Oregon Irrigation Company, which has already received partial payment for these water rights and to which the balance due will be paid by the settlers.

Pilot Butte and Powell Butte Canals. Another feature of the Company's proposal is that deliveries of 306 second feet and 114 second feet, respectively, shall be made to the Pilot Butte Canal and to the Powell Butte Extension of the Central Oregon Canal, the former at a point 1.4 miles below the headworks, the latter at end of main canal, distant approximately 18 miles from headworks.

There appears to be no warrant for providing works in connection with developing the North Canal Unit, to make free deliveries of water to these canals. The equitable arrangement would be to apportion the cost of such works ratably among all the canals or properties using them, on the basis of actual amounts of water carried for each, and such provision has been made in the adjustment of costs hereafter shown.

The canal as now partly constructed will, when completed, have a capacity not exceeding 1,050 second feet, and it could therefore deliver little more than the required supply of 720 second feet for the North Canal Unit and the 306 second feet demanded for the Pilot Butte Canal. In view of this condition, no attempt has been made in this estimate to provide for a supply for the Powell Butte lands, which is regarded herein as an entirely independent proposition which may or may not be handled in connection with the construction of the North Canal, whose cost should obviously be borne by the Central Oregon Irrigation Company, that company being the sole beneficiary thereby.

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*This item is excluded because the Railroad Company built the trestle at its own expense and owns it, although the Company claims to have surrendered right of way on account of it.

Cost of Completed Project. On the basis of apportionment between the North Canal system and the Pilot Butte system for cost of dam and headworks and main canal, as above indicated, the estimate of the completed project is as tabulated below, the figures being inclusive of a 25 per cent allowance for engineering and contingencies:

Item	Amount	Chargeable to*	
		North Canal System	Pilot Butte System
Cost of reproduction new, of existing works, per estimates hereinbefore detailed	$ 184,000	$ 129,000	$55,000
Cost to complete main canal between sta. 0 and sta. 74+60	43,000	30,000	13,000
Main canal from sta. 74+60 to end (16 miles)—Capacity 720 s.f. to 25 s.f.	170,000	170,000	....
Lateral B (17 miles)—Capacity 500 s.f. to 100 s.f.	265,000	265,000	....
Distribution system for 36,000 acres @ $10	360,000	360,000	....
Storage, 100,000 acre-feet at $2	200,000	200,000	....
Totals	$1,222,000	$1,154,000	$68,000

*Apportionment is on basis of 720÷1026=70% for North Canal system, and 306 ÷1026=30% for Pilot Butte system.

Cost per acre for North Canal system is, therefore, $1,154,000 ÷ 36,000 =$32.06. Called $32.00.

Adjustment with Central Oregon Irrigation Company. A proper adjustment with the Central Oregon Irrigation Company is a matter of balancing an account, involving certain credits for constructed works to be transferred to the purchaser and certain debits for works to be constructed by the purchaser for the use and benefit of the Company. This account, from the figures already presented in this report, would make up as follows:

Credits:	For value of existing works per detailed estimate hereinbefore shown		$184,000
Debits:	For portion of value of dam and headworks and main canal chargeable to Pilot Butte system (30% of $184,000)	$55,000	
	For portion of cost of completing main canal, chargeable to Pilot Butte system (30% of $43,000)	13,000	
	*Irrigation of 2200 acres of land at $30	66,000—	134,000
			$ 50,000

Common Ownership. In view of the fact that 30 per cent of the completed dam and headworks and main canal, has been charged against the Central Oregon Irrigation Company, ownership to that extent might be deemed vested in the Company, the entire works above the junction with the Pilot Butte Canal thus becoming a joint ownership proposition, with co-responsibility for maintenance and operation. It is assumed, however, that sole control and ownership by the State or Government, is the only arrangement that would be acceptable to all parties, such control and ownership, however, carrying with it the responsibility on the part of the State or Government to deliver 306 second feet of water to the Pilot Butte Canal and on the part of the Company to pay its 30 per cent proportion of the annual cost of maintenance and operation.

Cash Outlay Required. On this basis the actual cash outlay required to complete the project is estimated as follows:

Payment to Central Oregon Irrigation Co.	$ 50,000
Completion of main canal (Sta. 0 to Sta. 74+60)	43,000
Main canal below Sta. 74+60	170,000
Lateral B	265,000
Distribution system	360,000
Storage	200,000
Total	$1,088,000

Cost per acre—$1,088,000÷36,000-2,200=$32.19. Called $32.00.

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*This amount includes canals to deliver to each 40-acre unit.

Alternate Scheme. Before closing this report, a reference should be made to the possibility of developing this North Canal Unit in conjunction with the proposed irrigation of that large body of land lying immediately north of Crooked River and east of the Deschutes River. This latter project contemplates the irrigation of 100,000 acres of land, by diverting from the Deschutes River at a point about five miles below the present intake of the North Canal.

It would be possible to utilize the present dam of the North Canal Unit for this larger project, and estimates have been made which contemplate a concrete lined canal, following the location of the North Canal and Lateral B (see map) as far as Crooked River, and having sufficient capacity to serve the 38,000 acres of the North Canal Unit and the 100,000 acres lying to the north of Crooked River. These estimates, which were made by the United States and the State of Oregon in connection with general studies of Central Oregon irrigation matters now in progress, indicate a cost for this combined project of upwards of $50 per acre.

The utilization of a concrete lined canal instead of the earth canal contemplated for the North Canal Unit alone, would so reduce seepage losses as to require less storage than the 100,000 acre-feet provided herein.

Despite this saving on storage, however, it is plain that such a combined development, as compared with the independent development of the two units, would greatly increase the per acre cost for the North Canal lands. It is also a fact that the North Canal lands could not bear this increased cost, whereas the feasibility of the 100,000-acre unit is less seriously threatened by the higher cost involved in its development as an independent scheme. The prospect of financing the North Canal Unit and of securing early irrigation is far more favorable under a scheme of separate than under a scheme of combined development. The combined development has therefore not been favorably regarded, and reference to it here only made for the purpose of indicating that it has been considered.

Summary. For convenient reference the principal findings with respect to the North Canal Unit and the proposals of the Central Oregon Irrigation Company in relation thereto are summarized as follows:

1. The total area of project is 65,045 acres, of which 55 per cent, or 36,000 acres, is irrigable.
2. The per acre cost of the completed project will be approximately $32 per acre of irrigable land.
3. The storage requirement will be 100,000 acre-feet, which storage may be obtained in the proposed Crane Prairie reservoir on West Fork of Deschutes River.
4. The project calls for no unusual features, is simple of construction and is regarded as entirely feasible from both the physical and commercial viewpoints.
5. The initial cost of works already constructed on the project is found to be $220,000, and the estimated cost of reproduction new, $184,000.
6. The main canal is found to have sufficient capacity to serve only the requirement of North Canal project (730 s. f.) and that of Pilot Butte Canal (306 s. f.) as demanded by the Central Oregon Irrigation Company.
7. It is believed that the cost of dam and headworks and main canal above its junction with Pilot Butte Canal should be apportioned ratably between the North Canal and Pilot Butte systems, on the basis of capacity provided for each, to-wit: 720 s. f. for the former and 306 s. f. for the latter.
8. It is believed that the Central Oregon Irrigation Company should be charged the same rate as is charged other lands, for the 2,200 acres to which it has already sold water rights and which it desires irrigated from the North Canal.
9. The amount which should be paid to the Central Oregon Irrigation Company for the North Canal property, in the event of purchase is estimated to be $50,000, the obligations incident to this payment being the delivery, on the part of the purchaser, of 306 second feet of water to Pilot Butte Canal, and perpetual payment, on the part of the Company, of its due proportion of maintenance and operation cost of all works above the junction with Pilot Butte Canal.
10. The cash outlay required to build the project, including payment for the works and properties of the Company to be transferred to the State or Government, is estimated at $1,088,000.
11. Attention is called to the fact that all estimates above given are based on an assumption that the supply for Pilot Butte Canal will be 306 second-feet,

this amount being what has been claimed by the Company as its contract requirement. Should this supply be found inadequate, a larger proportion of the present canal capacity may be required for Pilot Butte supply and correspondingly less will be available for North Canal Unit. A readjustment will also be necessary in the storage supply for North Canal Unit. The estimates of cost would therefore have to be revised to meet such differing conditions should they prove necessary, but no such revised figures are here given as the charge would not be sufficiently large to be a governing consideration in connection with the North Canal Unit.

Appendix—By John H. Lewis. The foregoing valuation of the property and rights of the Central Oregon Irrigation Company, which may be of value in connection with the construction of the so-called North Canal Unit, has been arrived at upon the basis of "cost of reproduction" and includes only those physical or tangible elements of property which can actually be used as a part of the completed project, without any allowance whatever for intangible elements of value.

The Company believes they are entitled to some allowance for development expenses necessarily incurred in segregating the land and holding the project intact for many years as indicated in their statement of initial cost of existing works.

In view of the fact that the company has not agreed to turn over this unit to the State or the United States, or both acting in co-operation, for any figure which such agencies may consider reasonable, and in view of the further fact that water rights, plans and information secured under Chapter 87 Laws of Oregon for 1913, may ultimately come into the hands of private parties having ability to construct the project, and who will not be in the position of the United States, with respect to land ownership, it would appear that a more equitable basis for valuation would be to arrive at that value which would be assessed by a jury in case of condemnation.

The Company's contract with the State, and the State's contract with the United States do not expire until October 17, 1915. A five-year extension is allowed by the Carey Act and may be secured by the Company in which to complete this project, in view of the fact that the proposed works are partially constructed. Certain water rights are held under the old law, which may or may not lapse in case the Secretary of the Interior refuses to extend the contract, and these water rights may be of some value if the lands are restored to entry in 1915.

It therefore appears to me that a reasonable sum might be allowed the Company for development expenses and for holding the project intact, if construction is undertaken by others prior to the expiration of their rights.

In the above report, the reproduction cost of the dam and diversion canal is estimated at approximately 10 per cent less than the actual cost claimed by the Company. While it is doubtless true that some money was wasted in the construction of this work, it is believed that a jury would allow the actual cost to the Company if legitimate vouchers for such expenditures can be produced.

The amount allowed the Company for the partially completed works has been reduced by $66,000 or the estimated cost of irrigating 2,200 acres heretofore sold by the Company within the North Canal project. Attention is called to the fact that the Company's lien, or revenue from this sale, when fully paid, is only about $40,000. Rather than lose the $66,000 cash in case of sale, the Company would doubtless make some arrangement whereby the holders of these contracts, who had not made settlement, could exchange for unsold lands under the Pilot Butte or Central Oregon canals where the cost of reclamation would be somewhat less than under the North Canal. For sold lands, which have been occupied and improved, the Company could perhaps arrange to continue the irrigation of these lands through laterals from present constructed main canals. This would slightly decrease the area of land to which the cost of the project would be apportioned, and would increase the cash payment to the company to the extent that exchanges of land could be effected. Such an arrangement would overcome what is believed to be a minor inconsistency in the above report where $4 per acre is allowed the Company for constructing laterals to 978 acres of this sold land and for the irrigation of which land under the proposed project $30 per acre has been deducted from money to be paid the Company, of which amount $10 is for construction of laterals.

The foregoing report is based upon the Company's claim that only 306 second-feet of water must be delivered from the North Canal to supply lands

under the Pilots Butte Canal. For the North Canal Unit, seepage losses aggregating 50 per cent of the water diverted, are provided for. Existing information indicates that present losses in the Pilot Butte Canal are approximately 50 per cent. Therefore, to supply the 1.8 acre-feet between May 23 and August 20, which the Company in its contract with settlers "agrees to furnish and deliver . . . at or within one-half mile of the land to be irrigated," will require the delivery of 428 second-feet from the North Canal, instead of 306 second-feet, to supply lands under the Pilot Butte Canal.

This would make it necessary to charge 42 per cent instead of 30 per cent of the cost of the completed portion of the North Canal Dam and the diversion canal to its crossing of the Pilot Butte Canal, to the Central Oregon Irrigation Company, unless present losses are materially reduced by concrete lining or otherwise.

This increase of 122 second-feet of water for the Pilot Butte Canal would result in a corresponding decrease for the North Canal, or a reduction of 6100 acres in the area to be served, unless the North Canal diversion as now constructed is enlarged and a corresponding increase of storage provided.

Assuming therefore that the original cost, as claimed by the Company, of $219,220 will be allowed; that a development or segregation cost of $56,318 as claimed will be also allowed; that the amount of water for the Pilot Butte Canal is increased 122 second-feet and decreased to such extent for the North Canal lands; that the original cost plus cost of completing the North Canal to the junction of the Pilot Butte Canal is assessed 42 per cent to the Central Oregon Irrigation Company and 58 per cent to the North Canal; that the Company will care for the 2200 acres heretofore sold, and that the area to be irrigated under the North Canal project is reduced by 6100 acres to correspond with the reduction of 122 second-feet in water supply, we will have:

Total cost of the project	$1,252,500.00
Chargeable to North Canal Project	1,142,406.00
Chargeable to Pilot Butte Canal	110,094.00
Cost per acre for 29,900 acres North Canal lands	38.00
Payment to the Central Oregon Irrigation Company	165,400.00
Cash outlay required	1,142,406.00

The Company's offer to surrender its rights to the North Canal Unit for $300,000 seems somewhat excessive. The payment of this amount to the Company instead of $165,400 above estimated as reasonable will add $4.50 per acre to the cost of the project. The construction cost would thus be $42.50 per acre.

The cost of the project with reasonable payment to the Central Oregon Irrigation Company as above estimated is thus $38.00 per acre and within the value of the land when reclaimed.

JOHN H. LEWIS, State Engineer of Oregon.

July 10, 1914.

STORAGE REQUIREMENTS.

The total assumed irrigation use and domestic requirements for the full utilization of the flow of Deschutes River above Benham Falls is as follows:

Name	Area	Duty in acre-feet per acre		Diversion in acre-feet		
		At land	At diversion	Irrigating season	Non-irrig. season	Annual
Prior appropriators..	145,000	2.2—	4.0—	532,500	57,600	590,100
West Side Unit.....	20,325	2.2	3.45	70,000	10,200	80,200
North Unit.........	99,300	2.0	2.70	268,000	49,500	317,500
South Unit.........	48,500	2.5	3.97	192,500	24,200	216,700
Total	313,125	2.2—	3.53—	1,063,000	141,500	1,204,500

With a total assumed use during the irrigating season of 1,063,000 acre-feet, of which possibly 63,000 acre-feet may be required by the DesChutes Land Company project above Benham Falls, there remains a total assumed use during the season of 1,000,000 acre-feet, measured at diversion below Benham Falls. The average natural discharge of the river during the irrigating season for the period 1905-13, inclusive, was 532,340 acre-feet, which would not require storage. There would, therefore, have been required for the period, a net annual storage to provide 467,660 acre-feet for diversion below Benham Falls.

It is proposed to provide this storage in reservoirs located at Benham Falls and Crane Prairie.

Benham Falls Reservoir. The region occupied by the Benham Falls reservoir site is covered by pumiceous sand, referred to by Professor Russell as "pumiceous lapilli," so prevalent over the larger part of Central Oregon. Within an area extending from 15 to 30 miles eastward of the crest of the Cascade Mountains, and from Paulina Lakes on the south to Lava Butte or Benham Falls on the north, are a number of cinder or volcanic cones. Russell counts 42 of them and estimates that there are a total of several hundred within the area described. Numbers of lava flows of extremely varying characteristics exist in this territory, which is, in short, mainly built up by successive flows, in layers of erupted volcanic matter.

In a region of the character above described it is difficult to obtain any satisfactory basis on which to forecast reservoir seepage losses. The fact that the entire region is generally overlain to a great depth with volcanic ash and pumiceous sand, together with the more important consideration that the reservoir occupies the bottom of the main drainage outlet of the country, leads to a fair conclusion that losses will not be such as to make storage of water at this site impractical or uneconomical.

Above the Lava Butte lava beds a much older and denser basaltic flow extends for over a mile along the east side of the river.

Test borings show that this lava flow is over 100 feet thick and extends some 60 feet below the present river bed. That there are losses through this older lava flow is doubtful. None are apparent, and so far as can be determined there are none.

Borings at Dam Site A, Sheet No. 21, generally show the first 15 to 20 feet below the bottom of the canyon, to be sandy, surface soil, while the succeeding 40 to 60 feet is a dense, water-tight, clayey material, overlying sand, gravel and boulders.

Borings at Sites B and D (see Sheet No. 21) show less depth of this water-tight material than Site A, at the upper end of the canyon, while Holes E to K, inclusive (see Sheet No. 69) show more water-tight material so far as penetrated.

It seems reasonable to assume, therefore, that the finer material, consisting of volcanic dust and sand, which is the latest evidence of eruptive activity in this region, has been carried on downstream by gravel, were generally deposited until the lake bed was entirely filled, the coarser particles in this case sinking to the bottom first, followed by finer particles, until the almost impalpable dust was reached which lies over all the other deposits.

In "Geology and Water Resources of Central Oregon," by Russell, 1905, Bulletin No. 252, already referred to, the geology of Lava Butte and the lava beds of some ten square miles adjoining is given in much detail and in Professor Russell's customary interesting style. He says on page 114:

> "The lava completely dammed the former course of the river and caused a lake to form, which found an outlet across a ridge of acid lava, probably rhyolite, on its west border. The outflowing waters cut a deep, narrow canyon, through which the river now rushes, forming a series of cascades, known as Benham Falls. This feature of the river, and the fact that its waters spread into the lava during high-water stages, so as to regulate its flow below the obstruction, will be described a few pages later in connection with other characteristics of the Deschutes."

And again on pages 116 and 117:

> "The lava stream from Lava Butte, as already described, entered the valley of Deschutes River and formed a dam. The river, thus turned aside, began to erode a new channel across a spur of the old acid lava, which previous to the change formed part of its west bank. The new channel is about half a mile long, and as the task of deepening it to the depth of the old one is as yet incomplete, the waters form a series of rapids, to which the name Benham Falls has been given. The fact that the river has not as yet deepened its present channel to the depth of the adjacent portion of the old channel now occupied by recent basalt is also shown by its sluggish flow above the obstructions, where the still water is from 10 to 15 feet deep. For about one-half mile above the head of Benham Falls and for approximately 3 miles downstream from the foot of the rapids designated by that name, the river is margined on the east, by a rough, precipitous escarpment of fresh, black, basaltic lava about 40 feet high, which is cavernous and intersected by fissures. The river seems to have filled the interstices in the rock adjacent to the fresh lava over which it flows during ordinary stages, but when a slight rise is experienced, the water, after gaining a certain level, escapes into the lava and disappears from sight. At several localities along the border of the recent lava, the water of the river, during my visit late in August, was observed flowing into crevices in the rocks along the border of the stream, and it was apparent that a tendency in the river to rise would be efficiently checked in this manner. The greater the volume of the river the more efficient these natural subterranean spillways become. The water on escaping from the river finds its way through or beneath the lava, and, as there are good reasons for believing, again comes to the light, in part at least, in the bottoms of the canyons of DesChutes and Crooked rivers, at a distance of 30 to 40 miles to the north of the localities where it disappears. Opal Spring and other similar springs in the canyon of Crooked River, may reasonably be explained on this hypothesis.
>
> The efficient check on the rise of the waters of the DesChutes so provided, exerts a conspicuous influence all the way down its course below Benham Falls to the mouth of Crooked River, a distance of about 50 miles. The annual range in the height of the river throughout this section is only 8 or 10 inches, while above Benham Falls the seasonal variations in the surface level of the river amount to several feet."

The older formation, referred to by Russell as "acid lava, probably rhyolite," is classified by G. E. Parkhill as "hornblend porphyry."

That there are several localities along the border of the recent lava in the vicinity of Benham Falls where water from the river disappears is quite true.

The assumption by Professor Russell that these losses are sufficient to materially affect the range in height of the river is clearly shown by records of stream measurements at Benham Falls and Bend to be erroneous. The lesser range of river height below Benham Falls is accounted for by the very much greater slope of the river and consequent higher velocity, while the greater range of river height above the falls is due to the very much flatter slope already referred to and the resulting lower velocity.

Russell assumes that the losses by seepage into the lava during high-water stages are sufficient to provide the control which produces the well-known regularity in the flow of the Deschutes in its lower course. Stream measurements extending over a number of years at and above Benham Falls indicate that there is no loss of water from the river between the country of upper streams which combine to form Deschutes River and Benham Falls. The Benham Falls gauging station is located about 1¼ miles below the dam site selected for this reservoir. It seems probable from a consideration of the records of stream flow that the regulating cause of the flow of Deschutes River is the extensive and deep deposits of pumiceous sand covering the area drained by the headwaters of Deschutes River.

Gaugings of the river between Benham Falls and Cline Falls show no loss of water and very little, if any, gain from unseen sources. Measurements of stream flow cannot be made with sufficient accuracy to detect minor losses of water, although large losses are easily detected.

With reference to the origin of Opal Springs it was suggested by Russell that the supply of water for them comes from losses from the river above Benham Falls and passes through or under the peninsula between that point and Crooked River. Stream measurements show that the assumption that stream losses are the source of this supply is erroneous. If the supply of water to Opal Springs comes from above Benham Falls, the source of this supply is ground-water storage, and if the supply comes from the flow of the Deschutes it must take out from the river below Cline Falls.

Immediately below the reservoir site is a succession of falls which within a distance of 4½ miles have a total drop of 325 feet. For this reason it appears probable that any material reservoir seepage loss from the Benham Falls reservoir will be returned to the river within the limits of these falls; the more so, since the old river bed, down which some of the lost water would escape, when traced by following the trend of the most recent lava flow which filled it, would seem to rejoin the present river above the foot of the falls. It is this flow which pushed the old river into its existing course and solidified into the "Lava Beds" (see Sheets Nos. 21 and 71), around which the falls occur. Any seepage loss so returned will be available for diversion at points lower down the river, and there would be no actual loss from the flow of the river, providing the seepage loss and return does not exceed the minimum diversion requirements. The assumed minimum diversion requirements, which occur during the seven months of the non-irrigating period, amount to a total of 141,500 acre-feet for the season, and if the entire storage of 467,660 acre-feet required were provided in the Benham Falls reservoir, annual seepage losses from this reservoir would have to exceed 50 per cent of that storage before any actual loss of water to the land would occur under the assumptions as to use and seepage returns to the river.

It will be shown that economical distribution of storage between Benham Falls reservoir and Crane Prairie reservoir will require the storage at Benham Falls of approximately 400,000 acre-feet. It is estimated that the annual seepage loss from Benham Falls will not exceed 20 per cent of the maximum storage, or approximately 80,000 acre-feet. The proportionate loss during the non-irrigating season may be as much as 50,000 acre-feet.

Of the 141,500 acre-feet required during the non-irrigating season 60,000 acre-feet is diverted at the Aubrey Falls dam, which is 28 miles by river from Benham Falls and approximately 1,000 feet lower in elevation; and 17,500 acre-feet is diverted at the North Canal dam, approximately 12 miles below Benham Falls and 550 feet lower in elevation, while the first diversion point, Lava Island Falls, is five miles below Benham Falls and approximately 200 feet lower in elevation. For this reason it is believed that the seepage losses from the Benham Falls Reservoir, if any, will not in effect decrease the volume of available storage estimated, and no allowance will be provided in the plans submitted in this report.

Crane Prairie Reservoir. For a mile or so above the dam site on the northeast side of the reservoir, scoriaceous lava rock is exposed. It has been impossible to determine definitely whether there will be serious seepage losses through the rock. However, as the extreme height to which the water is to be raised is only 27 feet, it does not appear to be impracticable to prevent such seepage.

The existence of the large springs along Fall River and at the source of Spring River indicates the possibility that part of their flow may be lost by seepage from the river at Crane Prairie. These springs are partially accounted for by the discharge from Davis Lake, which passes beneath the lava beds. The drainage area of the West Fork of the Deschutes above Crane Prairie is uncertain, but it has been estimated to be 154 square miles. The run-off from this area for the period from May 1, 1913, to April 30, 1914, taken partly from actual records and partly estimated, was 257,740 acre-feet. The drainage area of the West Fork of Deschutes River at its junction with the East Fork is approximately 500 square miles, and the run-off for the same period was 844,000 acre-feet. These run-offs reduced to depths of water in feet distributed over the drainage area give a depth of 2.62 feet at Crane Prairie and 2.64 feet at the East Fork. As the average elevation of the entire drainage basin of the West Fork is approximately the same as that of Crane Prairie, this equality in run-off indicates that the springs referred to do not have the source of their supply from any particular point such as Crane Prairie, but that they are the concentration of ground waters whose sources are distributed over the entire drainage basin, and the concentration of the discharge at these points is the result of peculiar geological formation.

The annual seepage loss from Crane Prairie Reservoir has been assumed at 20 per cent of the maximum storage capacity. The full utilization of the irrigation resources of Deschutes River will in any case require that part of the storage shall be provided for at Benham Falls. It is evident, therefore, that in the ultimate irrigation development of the basin any error in the volume of seepage loss from Crane Prairie Reservoir can only affect the relative heights of the dams and the relative reservoir areas required at Benham Falls and Crane Prairie, providing the Crane Prairie seepage losses are returned above the Benham Falls Reservoir. That such will be the case is indicated by the springs already referred to.

As a practical consideration affecting the selection of a storage reservoir in a region such as this, where the formation is admittedly fissured and cavernous and where heavy underflows are known to exist, it must be recognizel that there is an element of chance in any of these surface depressions, termed reservoir sites, forming tight reservoirs.

It is impracticable to determine these matters by examination or experiment. All that can be relied on are results, acheved in reservoirs in other volcanic regions having similar characteristics. The most conspicuous example of these is the Clear Lake Reservoir in Northern California, a reservoir of some 450,000 acre-feet capacity, situated in a porous lava region, practically a part of the same series of volcanic formation of which the Deschutes basin constitutes the northern slope.

The Clear Lake Reservoir is actually underlaid in part by porous lavas and loose volcanic formation in which the natural ground water plane lies far below the surface. In spite of these unpromising conditions the upper soils have constituted a practically watertight blanket and seepage losses are comparatively small, showing that there is substantial reason to expect similar results in the Deschutes reservoirs.

Evaporation conditions for the Deschutes basin above Benham Falls have been assumed as similar to those about Klamath Falls, which is at approximately the same elevation above sea level. Observations there, indicate evaporation from lake surfaces to be approximately 3.5 feet of depth. This rate of evaporation has been taken for Crane Prairie. Reference to capacity and area curves for these reservoirs, Sheets Nos. 59 and 118, show a smaller total evaporating surface, if all necessary storage were provided at Benham Falls. Estimates show, however, that the cost of Crane Prairie storage is so much lower than that of Benham Falls, that its use to the maximum amount possible is justified.

Approximately half of the total yearly evaporation will occur during the filling period of 7 months, while the other half occurs during the irrigating period. This inequality of distribution is the result of the different atmospheric conditions of the two periods.

The run-off from Crane Prairie for the year 1913-14 was 257,740 acre-feet. By inspection of the records of the West Fork of Deschutes River since January, 1905, it appears that the year 1913-14 gave an excess run-off of approximately 16 per cent over the mean, and it may reasonably be assumed that Crane Prairie gave a similar excess run-off for that period. The mean annual run-off of Crane Prairie in the absence of better information, may therefore be taken as 222,500 acre-feet. The run-off for the irrigating period, May 1 to September 30, 1913, was estimated at 132,040 acre-feet. Assuming the same percentage of excess, the mean annual run-off during the irrigating priod, May 1 to September 30, is 113,500 acre-feet. There remains then, available for storage, evaporation, and seepage losses, 109,000 acre-feet.

By reference to the capacity and area curve for Crane Prairie Reservoir, it is seen that for a storage capacity of 95,000 acre-feet, an area of approximately 6,200 acres is covered. Assuming that the rate of evaporation will be 3.5 feet depth per annum, and that a mean area of half the maximum will be exposed to evaporation during the entire year, the evaporation loss during an entire year would be 11,000 acre-feet. The seepage loss has been assumed at 20 per cent of maximum storage or, say, 19,000 acre-feet per annum. The combined seepage and evaporation losses for the year, on the assumption of 95,000 acre-feet storage, would therefore be 30,000 acre-feet. If half of this loss occurred during the filling period it would not be available for storage, and the storage capacity, if designed strictly on this assumption, should be 109,000 acre-feet less 15,000 acre-feet, or 94,000 acre-feet, which would be available May 1. Subsequent to May 1, during emptying of reservoir, the seepage losses would not affect the storage requirement at Benham Falls, but the evaporation loss for this period would enter into the computation of storage required at Benham Falls and the net supply available for diversion to land. The evaporation for the year has been estimated at 11,000 acre-feet and for the irrigation period it may be taken as half, or 5,500 acre-feet. This, deducted from the supply available on May 1, 94,000 acre-feet, leaves 88,500 acre-feet net storage available at diversions.

Relation of Crane Prairie Storage to Benham Falls Storage. With storage for 88,500 acre-feet provided by Crane Prairie Reservoir there will remain 379,160 acre-feet net storage supply to be provided in Benham Falls Reservoir.

By reference to Benham Falls Reservoir capacity and area curve, it is seen that for 400,000 acre-feet storage, the maximum area is approximately 18,000 acres. At the rate of evaporation assumed, 3.5 feet depth per annum, the evaporation for the year will be 31,500 acre-feet. Half of this will occur after May 1, the beginning of the irrigating season, and storage for this amount, 15,750 acre-feet must therefore be provided in addition to the 379,160 acre-feet net storage required at diversions. The storage capacity required at Benham Falls is therefore 394,910 acre-feet.

The total assumed annual evaporation from both storage reservoirs is 42,500 acre-feet while the total assumed annual use, measured at diversion points is 1,204,500 acre-feet. Hence the total assumed annual demand for water will be 1,247,000 acre-feet. The mean annual discharge of Deschutes River at Benham Falls for the period 1905 to 1914, inclusive, was 1,210,000 acre-feet. The assumed annual demand for water is therefore approximately 2 per cent in excess of the recorded mean supply for the period observed. An actual shortage of this amount, the possibility of which is indicated by the records, would probably be seriously felt by the projects now being constructed without provision for storage.

For the period from 1905 to 1914, inclusive, the extreme variations from the mean run-off of Deschutes River were minus 11 per cent and plus 16.5 per cent, and as already noted for the projects constructed and proposed, with the assumptions made as to water duties, losses, etc., there would be a shortage of approximately 2 per cent in years of mean run-off; hence the extreme variation of the recorded run-off from the assumed annual demand would have been minus 13 per cent and plus 14.5 per cent.

It is necessary that the variation between the annual demand and the annual run-off be taken care of, by providing reservoir capacities sufficient to carry water over from years of excess flow, to years of deficiency. The annual 2 per cent shortage in mean run-off below the irrigation demand, cannot, of course, be made up, however large the reservoir capacity provided, and the general effect will be either to cause a slightly increased duty of water or decreased irrigable area. As the course of development will probably bring the least desirable lands under water last, and since there will doubtless be ample time to determine definitely many of the assumptions necessary for the purposes of this report, it is believed that it is not advisable to modify the plans adopted, to more closely conform to the assumed uses and losses. The acre cost would not be materially affected in any case by reduction of gross area to conform to assumptions. Moreover, further records of the discharge of Deschutes River will probably modify the value assigned to the volume of the mean run-off.

Discussions of water supply so far have been on the basis of a mean annual discharge. Full use of the total run-off, within economical limits of variation from an annual mean, involves storage to carry water over from years of high run-off to those of low run-off. Referring again to tabulation of annual run-off under "Water Supply—General," if the excess water of the year 1904-5 were to be fully utilized, it will be noted that the succeeding years of 1905-6 would not require the full amount. Moreover the next two years have an excess run-off, and hence cannot utilize it and, except as evaporation would have reduced it, the following years of 1908-9 would not require it all. With the relatively shallow reservoirs planned, the evaporation losses for such excess of water carried over for more than one season, become important. If, for example, the 1904-5 excess of 190,000 acre-feet of water above the mean volume were carried over to the succeeding year it would have been reduced by evaporation to a volume of approximately 150,000 acre-feet. The shortage of 120,000 acre-feet of water for this second year would leave only 30,000 acre-feet to be carried over to the fourth year of 1908-9, by which time it would have been largely consumed by evaporation.

ERRATA

As already shown, the storage required for mean years is 94,000 acre-feet at Crane Prairie and 394,910 acre-feet at Benham Falls, a total of approximately 490,000 acre-feet. It is seen that provision for this carry-over storage to the amount of the 1904-5 excess of 190,000 acre-feet of water, would require an increase of 39 per cent in reservoir capacity. Estimates show that the cost of storage will exceed $2.00 per acre-foot of capacity. The additional cost of the storage for 190,000 acre-feet at this rate will be approximately $400,000, which is close to $2.50 more for each acre of land irrigated. Inasmuch as the cost per acre for the construction of irrigation systems in this basin approaches the limiting cost which the land and climate will warrant, it is not regarded as economical to provide storage for the entire, combined shortage of the minimum years.

Crane Prairie Reservoir, exclusive of lands which it is assumed will be obtained from the Federal Government without cost, provides cheaper storage than Benham Falls Reservoir on account of land purchases required for the latter. So far as possible, therefore, consistent with volume of stream discharge, provision for carrying over from years of excess run-off to years of deficiency, should be at Crane Prairie Reservoir. Moreover, this reservoir is likely to be the first constructed in the irrigation development proposed, and for that reason, the largest practicable use of it should be made, in order that the greatest area of land may be supplied before the construction of Benham Falls Reservoir is required.

If, as is probable, the variation in annual run-off from Crane Prairie is similar to that of the main stream, approximately 35,000 acre-feet of the 190,000 acre-feet excess in maximum years, runs off at Crane Prairie and could be stored there more cheaply than at Benham Falls. It is also possible that there will be no appreciable seepage losses; if that should prove to be the case, storage of the amount estimated to be so lost prior to May 1, viz: 9,500 acre-feet. would be best provided there. It is proposed to increase the combined gross storage capacity of the two reservoirs approximately 13 per cent, or 63,350 acre-feet by raising Crane Frairie storage from 94,000 acre-feet to 110,000 acre-feet, and Benham Falls storage from 393,910 acre-feet to 442,500 acre-feet. This additional storage would have reduced the greatest shortage from mean annual run-off during the years 1905 to 1914, inclusive, to a little less than 7 per cent, and for irrigation requirements to a little less than 9 per cent. The plans and estimates herewith submitted are on this basis.

Benam Falls Dam will be required to raise the water level from elevation 4145.5 feet to elevation 4200.0 feet, or 54.5 feet, and Crane Prairie from elevation 4428.4 feet to elevation 4455 feet, or 26.6 feet.

Distribution of cost of storage, and water rights which it is found necessary to acquire for the several units proposed, will be made on the basis of total cost of storage reservoirs and the combined annual diversion requirements of the proposed units, in proportion to the water requirements of each unit.

DRAINAGE.

Under the subject of domestic water supply, reference has been made to the great depth at which ground water is encountered now. In this connection it should be noted that this condition obtains practically throughout the east side, where irrigation has been followed under the Central Oregon Irrigation Company's system for at least ten years. The effort of the town of Redmond to obtain a water supply from a drilled well was noted; also the depth of the well for the railroad water tank at Metolius, in the North Unit. There are a few wells along Willow Creek and Mud

Springs Creek which furnish water throughout the summer; otherwise the water for domestic supply is all hauled in tanks.

Under the Columbia Southern Irrigation Project, now the Tumalo Project, adjoining the West Side Unit on the south, where irrigation to some extent has been carried on almost as long as on the east side, the ground water does not appear to have been influenced. It is reasonable to expect that at most the ground water under the West Side Unit will be affected no more than under the Tumalo Project, for the bordering Deschutes Canyon is relatively deeper and nearer the land.

On the South Unit a well was noted, which although sunk 100 feet in the Dry River Bed did not encounter water. East of this, along the foot of Bear Buttes, there are a few wells; there are also a few wells and small springs around Powell Buttes, above the canal line proposed. Over the remainder of this unit, as over the North Unit, the water for domestic use and for stock, is all hauled in tanks, or obtained from the meager local precipitation and stored in concrete cisterns.

It is not believed possible, therefore, that drainage can ever become a serious problem in any of these units. There will without doubt be small areas here and there which will suffer by local water logging where the soil is immediately underlaid with hardpan or other impervious material. Such areas have been referred to under "Agricultural Survey" as "land locked." An effort has been made to eliminate all surface "land locked" areas or "pot holes," but at best there will always develop sub-surface conditions under some areas, which might better be called "drainage locked." It is impracticable, if not entirely impossible, to determine the "drainage locked" areas before the necessity for artificial drainage becomes apparent through irrigation. There are irrigation projects in which no drainage troubles have arisen and again others in which the drainage problems have exceeded those of the original irrigation. Costs for drainage, exclusive of tiling or farm drainage, have been as high as $10.00 per acre on some of the projects constructed by the Reclamation Service. Because of the impossibility of estimating the cost of drainage, in advance of irrigation, it has become the custom of many irrigation engineers to include no item for drainage in the estimates of cost for irrigation, and treat it entirely as a matter for future consideration. There has, however, been included in these estimates the equivalent, for each unit, of $1.00 per acre for drainage. It must not be regarded as a close estimate in any sense, but is considered a reasonable expectation of possible requirements.

AGRICULTURAL SURVEY.

The following chapter has been prepared by W. L. Powers, Assistant Professor of Irrigation and Drainage, Department of Agronomy, Oregon Agricultural College, from a preliminary survey.

Agricultural Development. Land in the North Unit was used for range purposes for many years, and was homesteaded for cultivation of the dry-farm plants about ten years ago. The first few years, these settlers devoted their time to clearing their claims. In 1911, the railroad was built through the district and grain growing, alternated with fallowing, became general. Reports from twelve good representative farmers within this unit show that in 1911 the average yield of winter wheat was about 15 bushels and the average yield of spring wheat was about 12 bushels per acre. The average acreage owned by these farmrs was 271 acres, and the average acreage farmed was 415 acres. Wheat was held to be the main source of profit; barley and oats were reported to yield 25 to 40 bushels per acre, and potatoes 50 to 100 bushels per acre. The twelve farmers reporting, had an average of $7030 capital and made an average profit of $437 in 1911. The average value of their land and improvements was given at $30 per acre, while the price five years previous to that, was placed at $15 per acre.

The year of 1912 was a season of heavy precipitation and the average yield of winter wheat in the district was about 20 bushels per acre, while for potatoes it was about 75 bushels per acre.

The College conducted a demonstration farm on a representative eighty near Metolius in 1912, of which the writer was acting superintendent. Without having much good fallow, winter wheat yielded 20 to 30 bushels per acre, spring wheat 18 bushels, spring barley 25 bushels and spring oats 41 bushels. Potatoes yielded 50 to 100 bushels, corn 7 tons and field peas yielded 1½ tons of hay or 10 bushels of seed on this farm.

The next season (1913) was a dry season. Winter wheat planted on the demonstration farm on well kept fallow, yielded 12 to 30 bushels. Some fields of winter wheat in the community averaged 15 bushels per acre, but the average for the whole district was about 10 bushels or scarcely enough to pay the cost of production.

The past season (1914) was more favored by moisture, but an unusually hard frost occurred in June and injured grain so that the crops scarcely paid for production the past season. As a result some of the farmers have had to go outside and find work, and several empty houses were seen by the writer during the recent inspection of these lands.

It is believed, however, that dry farming can be made permanently successful over the greater part of this area by practising the methods now used by the best practical farmers.

The College has demonstrated and urged the growing of field peas and dry-land alfalfa, potatoes and corn, instead of so much fallow. In the past two years the acreage of the two latter crops has greatly increased.

Agriculture within the West and South Units is largely undeveloped. Land, in its native state, in the West Unit is of very limited value. Dry farming has only been attempted on very limited areas. The Long Hollow irrigated ranch, located at the north edge of this project has been under cultivation 12 years. The manager estimated the yield of wheat at 25 bushels as an average, oats 50 bushels, and clover and alfalfa meadows at three tons per acre.

Another ranch at Cline Falls has been improved for several years. This is watered by pumping and the yield of alfalfa is reported at 2 tons per acre, while potatoes are said to yield 100 bushels per acre.

The main body of cleared land on the South Unit is found in the district near Powell Butte Land on the north slope of this Butte which is included in the project, is mostly cleared and is being dry farmed with fair success.

Climate Limitations. In general, the climate of the area is arid, with a low mean relative humidity and an abundance of sunshine. Strong breezes are common and cause some damage by blowing the sandier soils, but winds are not extreme and rarely reach a velocity of forty miles per hour.

The annual rainfall on the elevated plains of the North Unit averages about eleven inches and increases toward the foot hills and upstream. On the West Unit, extending a few miles west and north of Cline Falls, the average annual rainfall is about 12 to 14 inches, while for the South unit it runs from 10 inches near the Powell Butte, to some 15 inches north of Horse Ridge at the southwest end of the project. The maximum rainfall occurs in winter, with a secondary maximum in May and June. Rainfall is just sufficient for dry farming near the Butte and in the plains of the North Unit.

The growing season on the West and North Units will range from eleven weeks on the plateau, to four and one-half months in the canyon bottoms in the northeast part of each of these units. At the north end of the South Unit near the Butte, the average season between frosts will be eight to fourteen weeks, while in the main part of the proposed project, farther south, it will scarcely average eight weeks and light frosts are liable to occur any month. However, during the short growing season the clear air, warm sunlight, and free soil produce remarkably rapid growth under proper moisture conditions. It is possible to raise a little hardy fruit for home use in favored spots on the Powell Butte and in the lower part of the West and North Units, while south of the Powell Butte only the hardiest root crops and forage plants can be successfully grown.

Surface Geology and Soil, Origin. The area under consideration is entirely underlaid with porous basalt lava or occasional tuffs. There is a layer of hardpan or volcanic ash from six inches to several feet in thickness between the soil layer and the basalt in most of the northern and eastern parts of the district.

The river and its tributaries have cut canyons through the lava to a depth of several hundred feet in their lower courses, and in these, wind and water have assisted in forming a soil of relatively good depth.

The plateaus between these canyons are great plains covered with residual soil. In each unit is a group of buttes the lower slope of which could be watered, and the soil here is largely of colluvial origin. In general, the lands in this region are rather shallow and of a sandy nature, and require careful handling to avoid leaching and to keep up the humus content under irrigation.

Depth and organic matter content, as well as texture, have been considered in classifying the lands, and some finer distinctions have been made than is customary in Bureau of Soils Survey work. The textural names also vary slightly from their standards in order to bring out local comparisons.

Soils of the North Unit. The soils on this unit are mainly residual although there is a small amount of colluvial soil on the north slope of Juniper and Round Buttes. There is a small amount of alluvial soil in the canyons and draws at the north edge of the project.

Areas of Different Soils on North Unit.

Soil	Acres	Per cent
Fine sandy loam	59,000	59.0
Very fine brown sandy loam	28,000	28.0
Stony loam	4,000	4.0
Very fine sandy loam	4,500	4.5
Fine brown sandy loam	2,000	2.0
Fine sand	1,500	1.5
Silt	500	.5
Gravelly loam	500	.5
Total	100,000	

Fine Sandy Loam. Fine sandy loam covers about sixty per cent of this unit. It occupies most of the higher country around Opal City, Culver, and extends on north to Metolius and along the ridge east of Madras. There is a stony phase of this type on some of the ridges, and the northeast slope of some of the ridges is of a sandy character in very small areas. This type ranges in depth from twelve inches to 36 inches, but the average depth is close to two feet. The soil is light brown in color, is naturally well drained, free working, and is regarded as a safe soil to irrigate.

Mechanical analyses of chief types in the Project hereafter given were made by Mr. Cooter and Prof. Ruzek of the Agronomy Department, O. A. C.

Mechanical Analyses of Fine Sandy Loam.

Description	Town. S.	Range E.	Sec.	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt	Clay
Surface	11	13	21SE¼	3.68	10.68	10.90	25.03	18.22	24.72	9.82
Subsoil	11	13	21SE¼	3.96	11.00	10.06	25.64	18.60	27.40	8.10

Very Fine Brown Sandy Loam. Nearly all of the Agency Plains and a small area across the Willow Creek Canyon from this plain toward the south, is fine sandy silt loam. There are some 28,000 acres of this type of soil. This soil is of a medium brown color and is slightly sticky in places in the subsoil. The surface soil is freeworking. Where the rim rock is perpendicular, this type of soil extends out to within a few rods of the rim rock, but where the rim rock slopes off there is a slight strip of stony loam between this and the canyon. The soil is very uniform for so large an area. It averages about two feet in depth and ranges from fifteen to thirty inches in depth; a few places have even a greater depth. It is very important not to over-irrigate this soil, but it is believed that with careful handling, including the plowing under of clover and application of manures, that this soil can be profitably irrigated.

Mechanical Analyses of Very Fine Brown Sandy Loam.

Description	Town. S.	Range E.	Sec.	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt	Clay
Surface	10	13	13SW¼	2.36	9.68	16.34	28.88	14.46	26.04	2.34
Subsoil	10	13	13SW¼	7.8	14.87	14.58	24.80	14.58	20.34	3.03

Very Fine Sandy Loam. In the basin west of Culver and in various other basins north and east of Culver, we find the soil is somewhat darker in color and somewhat deeper and of finer texture, making a very fine phase. Where drainage is good, this soil should make a good ground for alfalfa under irrigation, but the drainage is imperfect in some places and these places will need to be irrigated with care.

Mechanical Analysis Very Fine Sandy Loam.

Description	Town. S.	Range E.	Sec.	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt	Clay
Surface	10	13	30SW¼	1.80	7.56	10.36	20.64	18.34	35.40	6.04

Stony Loam. On the ridges between Metolius and Culver and also east of Metolius and Madras, the soil is rather shallow and contains some stone and gravel. On the breaks of these ridges, the sandy surface materials has been largely swept away by wind, and the fine earth is somewhat sticky in places. A general class has been made of soil of this character, ranging from fine sand to heavy silt and containing considerable stone. At least half of this type of soil is too shallow or steep to be suitable for irrigation purposes, the land being mainly valuable for range purposes.

Fine Brown Sandy Loam. There is a colluvial soil on the north slope of Round Butte which is dark brown in color and contains a higher percentage of silt, with a good amount of organic matter a enough sand to be freeworking. There is some loose rock and juni but the fine earth is of very good quality and is classified as fine bro sandy loam.

Mechanical Analysis—Fine Brown Sandy Loam.

Description	Town. S.	Range E.	Sec.	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt	C
Surface	12	13	6SW¼	2.40	7.26	9.36	20.94	20.16	37.92	

Fine Sand. There is about 1500 acres of fine sand in the can bottom, south and east of Youngs, at the northeast corner of this u The soil averages 24 to 30 inches in depth, is well drained and is garded as a good soil for irrigation purposes.

Silt Loam. On the north slope of the butte between Youngs Gateway there is nearly a section of heavy silt loam. This is a str soil and contains enough clay to be somewhat sticky. It is only fa suitable for irrigation purposes.

Gravelly Loam. On the north slope of Juniper Butte, there is other small area of colluvial soil. The fine earth is fine sandy l but there is perhaps two per cent of secondary basalt fragments t are high in silica. This soil could be profitably irrigated. It is eight inches or more in depth.

Soils on the West Side Unit. The West Unit embraces two ty graphical divisions, namely: the upland and the canyon bottoms. plateau soils are of a sandy nature; they are interspersed with l outcrops and contain loose rock in places. They are mainly resid soils resulting from weathering of underlying basalt. Wind assisted some in bringing about the present soil arrangement.

Canyons cross the northwest part of this unit, running in a no easterly direction to the Deschutes River. These probably were for partly by erosion and partly by faulting. One of these, called Broad Canyon, probably was caused by a block of the earth's c settling down. Soil in these canyon bottoms has been deposited pa by wind action and partly by running water, in addition to the w of gravity.

Soils of the plateau have been divided into three types and t of the canyon bottom into four types. The following table gives name and extent of each soil type.

Areas of Different Soil Types on West Unit.

Soil	Acres	Per
Plateau Division		
Medium (loamy) sand	8300	4
Medium sand	1700	
Fine sandy loam	400	
Canyon Bottoms		
Fine sand	5300	2
Fine sandy loam	2400	1
Medium sand	1600	
Coarse sand	300	

Plateau Soils.

Medium (*Loamy*) *Sand* This is the prevailing type of soil extending over the plateau. This soil contains considerable pumiceous sand and enough silt and vegetable matter to give it a loamy character. Near the Cline Butte, gravity has assisted a little and this soil is most loamy here. Most of this land is undeveloped and is covered with juniper and black sage. The depth averages about eighteen inches, ranging from six to thirty inches and running shallower toward the north side of this soil area. The subsoil is similar to the surface, being slightly more yellowish and pumiceous. The soil rests directly on the porous basalt which is somewhat disrupted and porous near the surface, affording slow, natural drainage. The value of this soil is at least equal to that in the vicinity of Redmond for irrigation agriculture, it being of a very similar character.

Mechanical Analyses—Fine Loamy Sand.

Description	Town.	Range	Sec.	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt	Clay
Surface	15	12	8 E½	5.74	14.44	12.76	26.60	26.18	12.88	1.50
Surface	15	12	11 N½	4.38	12.88	12.28	25.26	24.52	17.35	5.82

Fine Sandy Loam. Towards the west part of this unit there are some depressions, the larger ones as much as half a mile in diameter. The soil in these is finer and deeper, being as much as four and one-half feet deep in the center of the larger basins and constitutes a finer phase of the main type. The soil is hard in the third foot. The vegetation is mainly yellow sage, indicating that alkali is to be expected with irrigation. Areas that are badly land locked have been excluded from the proposed project. The soil is comparatively good in plant food content, but would need to be irrigated very cautiously. If this is done it should be a good soil for alfalfa.

Medium Sand. A sandy phase occurs over most of the three sections bordering the river above Cline Falls. This soil is mostly sandy on the northeast slope, approaching the character of the medium sandy loam in the basin to the south and west of the area. It requires careful handling to prevent blowing or erosion by irrigation water and needs humus to increase its water capacity. The depth is twelve to 24 inches, averaging about eighteen inches. There is less rock but a little higher percentage of sand here than in the vicinity of Redmond. This soil is only fairly suitable for irrigation.

Canyon Bottom Soils.

Fine Sandy Loam. There is a fine sandy loam in the Buckhorn Canyon opposite the new wagon grade, and in the flat north and west of LaFollette Butte, which is partly watered from Squaw Creek at present. The soil is two to three feet and more in depth and becomes more loamy with irrigation. Fine sandy loam also occurs on the flat

Mechanical Analyses—Fine Sandy Loam.

Description	Town.	Range	Sec.	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt	Clay
Surface	14	12	18 N½	3.84	10.00	12.54	24.22	22.38	22.46	4.38
Surface	14	12	7 N½	1.03	8.00	10.72	19.36	27.48	26.33	7.08

Fine Sand. Fine sand occurs chiefly in broad canyons south of LaFollette Butte and in the areas north of Long Hollow. This soil is also two or three feet and over in depth, is less inclined to blow and becomes more loamy when irrigated, due to decomposition of the minerals and increase in the organic matter content. It is considered a suitable soil for irrigation purposes.

An area of fine sand below Odin Falls one mile, is underlaid with wash gravel at sixteen to eighteen inches from the surface. This soil is inclined to drift, and is covered with a sparse growth of yellow sage. It would require as much water as any soil in this unit and does not appear to be very desirable.

Mechanical Analysis—Fine Sand.

Description	Town.	Range	Sec.	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt	Clay
Surface	14	12	9	6.62	11.12	11.02	27.94	28.58	9.88	5.36

Medium Sand. Medium sand occurs in Long Hollow and Lower Buckhorn Canyons and also east of LaFollette Butte. The soil is eighteen to 36 inches in depth and is covered with antelope brush. The coarse sand is largely pumiceous material and will become of a somewhat more loamy nature with irrigation. This soil will require more irrigation the first few years at least, and it will probably cost about all it is worth to irrigate it.

Coarse Sand appears on two ridges east of LaFollette Butte and covers an area of about 250 acres. It is very similar to the medium sand only that it is slightly less desirable.

Soils of the South Unit. A very general examination was made of the soils of this unit.

Areas of Chief Soil Types on South Unit.

Soil.	Acres.	P. C.
Medium to coarse sand	35,000	72.9
Fine sand	4,500	9.4
Fine sandy loam	4,000	8.3
Fine (loamy) sand	2,500	5.2
Undetermined	2,000	4.2
Total	48,000	

Medium to Coarse Sand. East of the end of the Arnold Ditch are several sections of medium sand. This sand contains much pumiceous off from the prominences and drifted into the basins between these places where the country rock is exposed. The west part of this area lies fairly well, and a good proportion of this area is included in these tillable basins. Farther east towards the lava flow, south of Alfalfa Postoffice, the country becomes more broken and there is much floating rock, in the low areas, to be removed before the land can be cultivated. East of the lava flow there is also a large area of medium sand that is separated from the country rock by a layer of hardpan. The west side of this area, near the lava flow, contains a former river bed and is deep gravelly sand that would require large quantities of water for its irrigation. The average depth of this soil is about sixteen to eighteen inches except in the river bed where it is very deep. The season is so short that it is doubtful whether alfalfa would succeed. It is doubtful whether the cost of reclamation of this soil, which is the main type of this unit, is not more than its present value would justify.

Mechanical Analyses—Medium to Coarse Sand.

Description	Town.	Range	Sec.	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt	Clay
Surface composite	17 18	15 13	34 & 25 16 & 20	4.96	16.36	19.70	25.22	17.50	14.36	1.92

Fine Sandy Loam. Fine sandy loam occurs on the northeast slope of Powell Butte and also there are a couple of sections of land of this character in the southeast part of the project, on the north slope of Horse Ridge. The soil will average nearly three feet in depth and is a good soil for irrigation purposes. It is dry farmed successfully at present, in the Powell Butte district. This is the best soil in this unit.

Fine Sand. On the northwest slope of Powell Butte, wind has assisted in the soil formation, and the material deposited is fine sand. The depth of this soil averages about eighteen to twenty-four inches though it runs as much as three feet or more in depth in some places. The soil is being successfully irrigated in this community at present.

Medium (Loamy) Sand. Below the fine sandy slopes of the Powell Butte there is medium (loamy) sand extending out onto the plain. This soil is very similar to the soil in the vicinity of Redmond and can be successfully irrigated. The conditions here in general are similar to those in the vicinity of Redmond.

Plant Food Content. In general, the soils of this Project contain a medium per cent of plant food, and their limited depth limits the total quantity. The soils are, in general, a little stronger and more productive in the finer types at the lower elevations tow the north, and on the north slopes to the north of the buttes. composition of the chief soil types is given in the following ta together with a more detailed discussion of plant foods in soil, by the station chemists; the composition of soil from the mond Demonstration Farm is given for comparative purposes. sum is much used on legumes in the Redmond district but a la profit was obtained from using sulphate of potash on the Der stration Farm near Redmond.

Soil Analyses. Chemical analyses of soils from the areas gated were made by R. H. Robinson and R. F. Beard of the chem laboratory at Oregon Agricultural College, with the following resu

Soil Analyses.

Description.	Township.	Range.	Section.	Total potash (K₂O) per cent.	Total phosphorus (P₂O₅) per cent.	Volatile matter per cent.	Total nitrogen (N) per cent.	Total alkali per cent.
North Unit:								
Fine sand (Christensen's)—								
Surface	9	14	22 SW¼	....	.197	3.68	.06	....
Subsoil	......	......	....	....	....	6.26	.08	....
Very fine brown sandy loam (Anderson's)								
Surface	10	13	13 SW¼	1.46	.20	4.21	.09	.056
Subsoil 24 in. to 30 in.	......	......	....	....	.17	3.91	.064	.009
Fine sandy loam (Metolius Experiment Farm)—								
Surface	11	13	21 SE¼	....	.18	4.10	.08	....
Subsoil 24 in. to 30 in.	......	......	....	....	....	5.09	.06	....
Very fine sandy loam (Lucy's)—								
Surface	12	13	6 SW¼	....	.16	4.04	.08	.044
Subsoil 24 in. to 30 in.	......	......	....	....	....	4.15	.06	.044
Hardpan	12	13	....	....	....	....	....	.010
West Unit:								
Medium (loamy) sand (Crossroads)—								
Surface	15	12	8 E½	1.61	.221	3.15	.065	....
Fine sand (Broad Canyon)—								
Surface	14	11	19 SW¼	1.63	.206	2.37	.093	....
Subsoil, 3d foot.								
South Unit:								
Medium to coarse sand—								
Surface (composite)	(17 (18	15 13	34, 25) 16, 20)	1.96	.206	3.41	.062	....
Redmond Demonstration Farm—								
Surface	15	13	3 SW, SW	1.66	.23	....	.07	.006
Second foot	......	......	....	1.59	.22	....	.05	.015
Third foot	......	......	....	1.44	.20	....	.04	....

The following comments on plant food content were made b
H. V. Tartar, Chemist, in submitting results of analyses:

"By way of comment I will say that the determinations of volatile matt made do not show the actual organic matter present. There may have be some changes in the inorganic matter during the determination. This we ha not had time to check up. The organic matter is, in my opinion, somewh less than that indicated by volatile matter."

"The amount of phosphorus present in these different soils is a little und the average for soils of the Northwest. It is not low, however, and is e dently present in sufficient quantity for crop production."

"The figures for nitrogen, one of the very important plant foods, are u formly low. As a rule the productive soils of Eastern Oregon contain 0.15 to per cent of nitrogen. There are productive soils which contain somewhat le These samples are low."

"The potash content is fair—somewhat near the average of soils fr Eastern Oregon."

"As shown by our rapid determinations, there are some alkali salts prese in these soils. It is not high, however. Thus far we have not had an opp tunity to get at the alkali salts more closely, so as to give an idea of wh kind of salts these may be, whether chlorides, sulphates, etc."

"For comparison I have inserted an analysis of soil taken from the Redmo Demonstration Farm. (See Oregon Agricultural College Experiment Stati Bulletin No. 119.) It has been irrigated for seven years. These figures m aid somewhat in judging the fertility of the samples sent in."

Irrigation. Irrigation on the north unit is almost untried. Abo one-third acres of fine sandy loam at Metolius was given a two-in irrigation by the writer in 1912, using the furrow method. T soil works well under irrigation. Moisture added, spread a go distance horizontally and was taken up at a medium rate a retained well. It was forty-eight hours after irrigation before t soil was dry enough to crumble properly under irrigation. The is a noticeable tendency for this soil to pack and crust, so it quires cultivation at the proper time. A small area of san soil below the springs at Young's is being irrigated. A relativ large amount of water is required for this soil.

The fine sandy loam, which is the leading type of soil on t north unit, has been found to have a relatively high usable wat capacity and a very light volume weight per cubic foot, due to t pumiceous material contained. The maximum capillary water ca city and volume weight under field conditions for the first foot this fine sandy loam on the Metolius Demonstration Farm, has be measured. The methods used were to take duplicate samples soil in stubble land, with sheet metal cylinders one foot long a one-fifth cubic foot capacity. These samples were saturated, drain to constant weight, for instance, thirty-six hours in the natural fi condition, after which the total moisture content was determin by oven drying. The weight per cubic foot of the dry soil w found to be sixty-five pounds, and the maximum capillary capac thirty-five percent, although the moisture content will drop rapi to about the twenty-eight percent point, before the soil is dry enou for proper cultivation to be given. This soil contains three and o half per cent moisture when air dried. The pumiceous sand see begin to fire in this soil when the moisture content drops to ten o twelve per cent. Crops are checked in their growth at about thre per cent above this so-called wilting point, and on this basis irrigation would be needed when the moisture content drops to abou the fourteen per cent point. This difference between the excess and deficiency point is at least fourteen per cent. Now fourteen per cent of th dry weight of the soil per cubic foot, or sixty-five pounds, is nine an one-tenth pounds, and this, divided by five and two-tenths, the weigh of an inch-foot (or "board foot") of water in pounds, is one and seventy-five hundredths inches depth of usable water per cubic foo or per acre foot, that theoretically could be stored in this soil. Th water capacity could of course be increased under irrigation farmi which could be handled so as to increase the organic matter conten of the soil.

Soils of finer texture from this unit of the project, would hol nearly two acre inches of water per acre foot, while the coarser textured soils would probably hold not over one and one-half acr inches per acre foot. The shallowness of these soils would prohibi extensive leveling, and the furrow method of distributing wate is recommended, at least for all of the undulating soils in this unit.

On the West Side Unit, where irrigation has been practiced fo several years near Cline Falls and in the canyon bottoms, it has creased the organic matter content of the soil and decreased th tendency to blow. The maximum capillary capacity of the fin loamy sand on the upland division of this unit has been found to b about thirty-two per cent, and when air dried this soil contains abou two and one-half per cent moisture. The lower limit of usable moistur is estimated at thirteen per cent and the upper limit at twenty-five pe cent, leaving twelve per cent usable moisture. The weight per cubic foo of dry soil here is about seventy pounds. On this basis, the usabl water capacity per cubic foot is eight and four-tenths pounds, whic is one and sixty-one hundredths acre inches per acre. This is lo the virgin soil and the usable water capacity could be increased b practical methods of irrigation farming.

The underlying country rock in this unit, interrupts the downwar movement of irrigation water and is a great aid in the horizonta movement of moisture applied in furrows. The furrow method distributing water should be most generally used on this unit.

Medium to coarse sand, similar to the medium to coarse sand o the South Unit, has been irrigated at the east end of the Arnol Ditch southeast of Bend, and also near the Alfalfa Postoffice, fo several years. On account of the coarse texture of this soil it ha required a relatively large amount of water. The average yie of alfalfa in the latter community has been about one and one-h tons per acre. Furrow irrigation is practiced in these communiti

Fine sand, adjoining the fine sand area on the north slope Powell Butte and just north of the South Unit of this project, being successfully irrigated by the furrow method, and is regard as a good soil for irrigation purposes.

Probable Duty of Water. Since the duty of water varies wit a project according to the soil type, more than any other one thi fixing the same duty for a whole project often works a hardship settlers located on the coarsest textured soils. It is believed t the duty on each of the units should be adjusted according to chief types of soil in each unit.

On the North Unit, if the fine sandy loam requires about t and one-quarter acre feet per acre per season, then the very f brown sandy loam which is second in extent could be allowed ab one and three-quarters acre feet. For the very fine sandy loa if located where it will receive water from higher land, being a s of good depth, and relatively high usable water capacity, one a three-quarters to two acre feet per season would be a comparativ good supply, considering the type of soil. The fine sand at northeast corner of this unit will probably require three acre f per season, at least for the first few years. The colluvial soils, t is, the fine brown sandy loam, and the stony loam and the grave loam, would require about as much as the fine sandy loams, to equally well provided for.

On the West Side Unit, the main type of soil on the plate which is the medium loamy sand, will probably require two or t and one-quarter acre feet per season. The medium sand will pr ably need two and one-half acre feet, and the fine sandy loam more than one and three-quarters to two acre feet per season. the canyon bottoms, the fine sand will probably require fully t and one-quarter acre feet per season, while the fine sandy lo should do as well with two acre feet, and the medium sand sho receive perhaps two and one-half acre feet per season.

On the South Unit, the fine sandy loam in the Powell Butte trict will require one and three-quarters to two acre feet, the medi (loamy) sand and the fine sand, two to two and one-quarter a feet, while the medium to coarse sand on the south part of the u will require perhaps two and one-half acre feet, at least for the fi few seasons.

It would seem especially important to make a slightly higher d for the land on the Agency Plains, that is, the fine sandy silt lo because here extensive irrigation might result in serious soil inju

Alkali. The lands in this district are comparatively free fr danger of serious trouble with alkali because the water is secure directly from the snow covered mountains and does not contain seepage from irrigated lands in any appreciable quantity; also, because most of the region has natural under-drainage through the porous lava rock. Except a few small pockets, practically all of the West and South Units are situated so as to have good natural drainage and be relatively free from danger of alkali trouble.

On the North Unit, the fine sandy loam and fine sand have good under-drainage, but the very fine sandy loam and very fine brown sandy loam have less perfect drainage and enough alkali to require careful watering if alkali trouble is to be avoided. It is probabl· however, that not more than five or ten per cent of this unit will be subject to serious alkali trouble if irrigated.

Samples were collected from the surface and subsoil, of the type most apt to give alkali trouble, and the total alkali as determined is given in the last column of the table of "Soil Analyses."

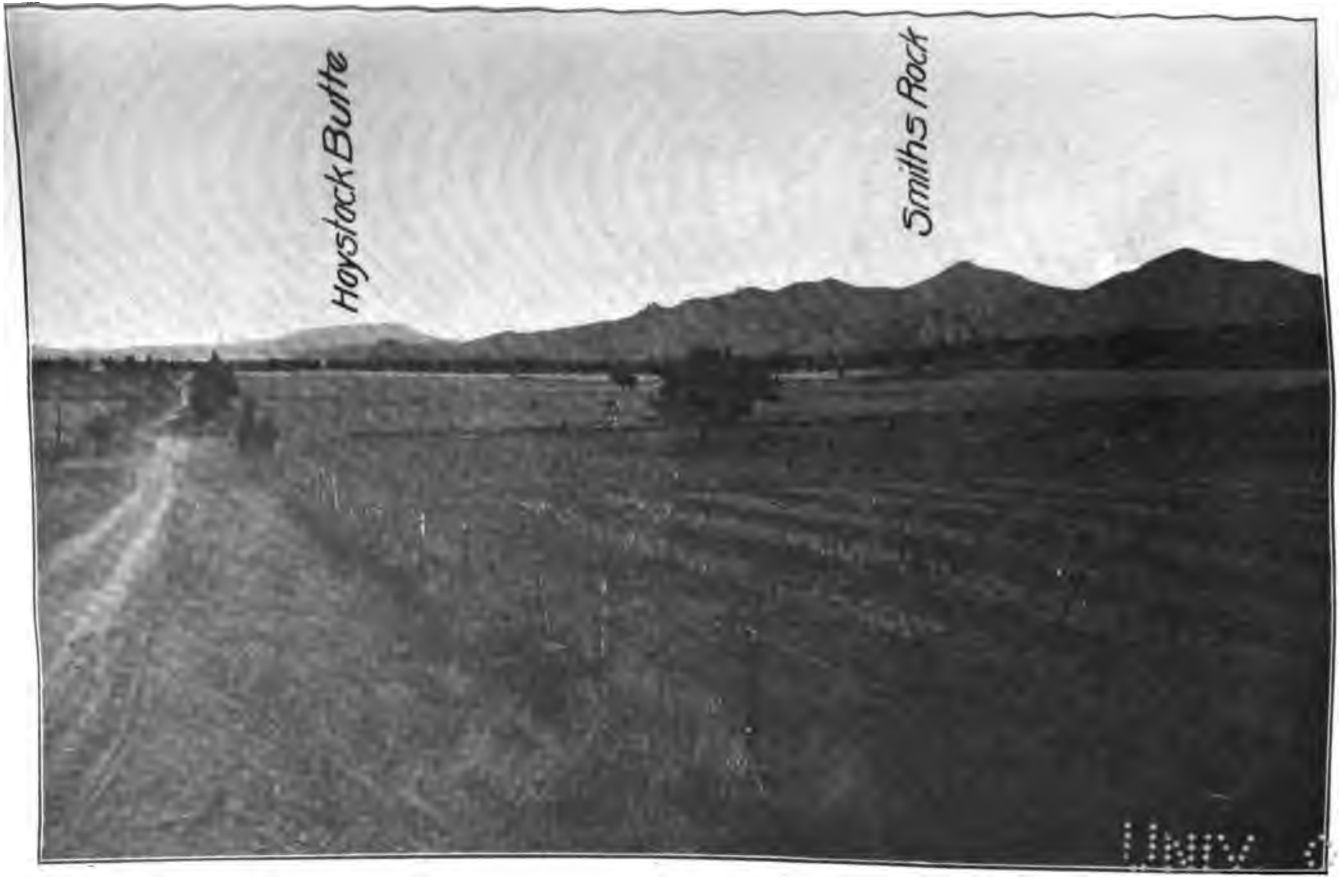
Drainage. In general, drainage on the North Unit is fairly good. The hardpan under the surface seems to run at a uniform depth and appears to be fairly free from such formations as are known as hogbacks and pockets, which interfere with under-drainage. The hardpan is somewhat porous, and will take up fifteen to twenty per cent moisture. The country rock immediately under this hardpan is generally porous and disrupted so that it is believed there will be some slow under-drainage through most of the substrata on the North Unit if irrigated. Irrigation will also have a tendency to soften this hardpan layer and to increase slightly the depth of the soil. There will be a tendency for irrigation to cause the packing or running together of the fine sand, particularly where a little clay is present in the subsoil, though it is believed that careful cropping and cultivation will offset this tendency. Some of the basins containing a very fine sandy loam are imperfectly drained, and in time may develop a little alkali trouble, if irrigated. The subsoil on the Agency Plains also shows a tendency to be sticky and cement. This soil can be expected to give some trouble, but it is believed that it can be handled by using clover and barnyard manure on the ground every few years. The surface slope is about twenty-five feet per mile, and there is very little chance of any water standing over any considerable area of the surface. There are good outlets on all sides of the Plain, and it is very probable that vertical drainage could be provided.

Drainage on most of the West Unit and South Unit is fully as rapid as is desirable. There are a few pockets on each of these units which are land-locked, but most of these have been excluded from the area under consideration, and they are not extensive enough to materially affect the project.

Probable Value of Irrigation. At present the area included in th
North Unit, is a second class dry farming district. The averag
yield of the leading crop, wheat, is about fourteen bushels per acr
and since about half of the land is in fallow each year, or uncroppe
the average annual yield is perhaps six or seven bushels per acr
The present system of farming, to grain and fallow, includes litt
or no provision for maintaining the fertility of the soil. Most
the water for live stock has to be hauled from the nearest railwa
station, and largely for this reason little live stock is kept an
almost no manure applied to the land.

In general, land that will produce enough to pay for the cost
production by dry farming, has sufficient usable water capacit
to make it fairly good soil for irrigation purposes. In general, soi
eighteen inches or more in depth in this region will make fair soi
for irrigation purposes, provided they lie fairly well. Most of th
land now dry farmed in the North Unit will meet this qualification
to depth, and the topography in general is favorable for irrigatio
farming. A good proportion of the land still in a raw state
this area, is also fairly suitable for irrigation farming. The
are perhaps three sections of land, or probably two thousan
acres, mainly the tracts designated as stony loam, and occupyin
the ridges east of Madras and Metolius and the breaks sout
of Madras, which are largely too shallow or too steep to be su
cessfully irrigated, and in fact, it is largely range land. Also
the broken country south and east of Section 4 in Range 14 Eas
Township 10 South, some land is too shallow or too steep to
suitable for irrigation. Otherwise, it is believed that the lands
the North Unit will stand irrigation, although the finer texture
soils will need to be handled carefully if irrigation is to be
thorough success.

If the North Unit were irrigated, alfalfa and clover would easi
become the leading crops. Alfalfa could be used in a short rot
tion on the soils that are two feet in depth and could be used f
fairly permanent meadow on the soils of greater depth. Where th
soils are less than two feet in depth, clover would be a much saf
crop to use, and should be used in about four year rotation. It
believed that the average yield of legume hay, of 3 tons p
acre, could be depended on and it is very possible that this avera
might even be increased. Barley should be the leading small gra
in this district under irrigation, and should yield 50 to 60 bushe
per acre, at least. Barley would serve as a nurse crop in seedin
down meadows, and would furnish grain for stock. Oats and fie
peas should also be used to some extent for grain feed. Corn, p
tatoes, and roots should also become staple crops and should
used in rotation with the clover and grain. These crops are p



IRRIGATED LANDS BETWEEN REDMOND AND TERREBONNE, LOOKING NORTH TOWARD HAYSTACK BUTTE AND SMITH'S ROCK.
PLATE XV.

marily dairy and hog feed, and the manure from these animals is needed to build up and keep up the fertility of the soil and to bring it into a more intensive state of production, which is possible under irrigation farming.

The advent of irrigation on these lands, then, would mean a greater diversity of production and more intensive methods. It would mean crop surety, closer neighbors, more shade, water for live stock, and less dust. It would compel closer cooperation.

The lands on this unit are in a fairly compact body, with the least desirable land on the outside. They are mainly cleared, and require a comparatively small amount of leveling. Good transportation facilities are already at hand, and there is a goodly number of settlers already established in this area. Their knowledge of moisture conservation gained by dry farming would be an asset in irrigation farming, though their habits of extensive farming, and their machinery now on hand would probably prove an obstacle to any change.

Everything considered, it appears that it will cost about all it is worth to bring these lands under irrigation, from an agricultural standpoint, but it is believed desirable from the standpoint of the commonwealth and from the standpoint of the settlers themselves, to develop these lands by irrigation. Water, as well as land, can be expected to increase in value in Eastern Oregon in the future.

The prevailing type of soil on the upland of the West Unit is practically the same as that in the vicinity of Redmond. The productive capacity of this district, under irrigation, would at least be equal to that of the Redmond district. The soil is at least as deep and appears to contain less stone. The cost of clearing, including plowing, on these uplands, will run about $15 to $25 per acre. From the farm survey, we find that the average cost of clearing 16 farms under the Central Oregon Irrigation Company's project was $23.57 per acre, and for clearing 6 farms on the Tumalo Project, the cost was $16.70 per acre. The average value of land and improvements on the 16 farms mentioned above was given as $70 per acre in 1912. The net profit per farm is low, because many of the places were being improved as fast as funds were available. The average total investment in these sixteen places was $22,400 per farm, and the net profit for 1911 was given as $750 per farm. The average yield of alfalfa hay and clover hay on these farms for 1911 was given at 2.67 tons per acre.

The Agricultural College conducted a demonstration farm on the medium (loamy) sand soil near Redmond in 1912, and the writer was superintendent of this farm. The average yield of clover and alfalfa on this farm was a little over 3 tons per acre. Corn yielded 16 tons of fodder, rutabagas 25 tons, mangels 20 tons, field peas 3 tons acre. The corn and mangels received a moderate application of stable manure, and the row crops were on clover sod land. The quantity of water used was considerably less than the one and eight-tenths acre feet per acre allowed. This shows something of the possibilities of this district, where the best modern methods are employed. The above named crops are the ones best adapted to the West Side Unit, particularly the plateau division. They are primarily dairy and hog feed, and dairying and hog raising are the most promising types of farming for this district. In the Canyon bottoms, the climate is somewhat better, and some more delicate crops can be grown. Clover and alfalfa should be the leading forage crops here, and the yield should run from 2.5 to 3 tons per acre. Clearing in these canyon bottoms consists largely of removing sagebrush and antelope brush. There is not much loose rock and but few trees to be removed. From the farm survey above referred to we find that it cost 6 farmers on the Squaw Creek project an average of $8.60 per acre to remove the scattering juniper and sage from this land and get it ready for the plow. The average capital invested in these farms was $20,957, the average net profit per farm $1400. The present average value of land in the canyon bottoms irrigated from Squaw Creek, is estimated at $60 per acre.

In general, these lands are as suitable for irrigation purposes at least as other lands around Laidlaw and Redmond. A few forties south of Tetherow Bridge, and south and east of the Buckhorn Canyon grade are rather shallow and very stony. They are not very desirable for irrigation purposes, and could well be excluded or left for future development. A few hundred acres of fine sand, underlaid with wash gravel on the flat a mile northwest of Odin Falls, is of rather doubtful value for irrigation purposes. It is also doubtful whether it will pay to water a small area of coarse sand lying east of LaFollette's Butte. Aside from these small areas, the lands of this unit are regarded as being fairly suitable for irrigation purposes, and it is estimated that the relative value of irrigation on these lands would be about $45 an acre.

Lands under the South Unit near the Powell Buttes which are of a colluvial character, are fairly well suited for irrigation purposes. They are mostly cleared at present. Just south of the Powell Butte station, and in places too close or too far from these buttes, the land is less than eighteen inches in depth. There are places on the northwest slope where the fine sand will be subject to erosion.

A few farmers, located under the Central Oregon Irrigation Company's ditch on similar land which has been irrigated several years, were interviewed in 1912. The average yield of alfalfa and

1911 was $550 per farm. The net profit is modest because the places have been brought but recently into profitable productio and are still being improved.

This part of the unit north of the buttes will produce 2 to of alfalfa or clover and 125 to 175 bushels of potatoes, or 25 to bushels of grain. The average value of land, unirrigated, w given as $20 in 1912; for the irrigated land it was given as $7 This will indicate the value of irrigation. There is also a sma amount of colluvial soil on the north slope of Horse Ridge. T climate there is less favorable and this land is still uncleared.

The medium to coarse sand, which is the main type on the Sout Unit, where free from rock, can be cleared for from $12 to $1 per acre, but the stony portions of this will cost from $25 to $5 and more, per acre to clear up. Several farmers were interviewe on medium sand in the vicinity of Alfalfa Postoffice, where th soil is at least as good as the medium sand on the South Unit. Th average yield of alfalfa and clover hay in 1911 on these farms wa one and one-half tons per acre, rye hay yielded one ton per acr and oats one ton per acre. The value of several farms, partly improved, ranged from $40 to $60 per acre, as estimated by the owner

The most promising crop for the medium sand on the South Uni with proper moisture supply, would be clover, rye, hay, rape, artichokes and hardy root crops. It is estimated that clover woul yield from one to two tons per acre.

Modern Irrigation Farming. In the above discussion, the probabl attainments of the average farmer have been kept in mind. Th difference between the probability and the possibility of this section, as of any other, is considerable. Under irrigation there i always a tendency for the soil to become compacted, but the extr root development, with proper handling, should offset this tendency. With irrigation farming, the crops removed are larger, and as a result, larger amounts of fertilizer must be returned t the land in refuse. It is important in irrigation farming, more tha in other kinds of farming, to practice a careful rotation of crops, that will permit the growing of clover or some other soil building crop on the land every few years, and furthermore, that will permit plowing up the land deeply at frequent intervals, so as to maintain a good state of tilth and a large usable water capacity. This rotation should also permit the growing of a good proportion of cultivated crops each year, as such crops will require less water an will use it later in the season than do the meadow crops. A rota tion of soil building crops, together with the application of manure.

maintains the water holding capacity and fertility, and l the water cost of dry matter. Larger amounts of manure ca used without making the soil too open, where irrigation is pra and deeper plowing can be done. By the use of crop rotatio cluding legumes, and the use of manure, a free working can be built up and kept in a higher state of production wit aid of proper irrigation. Irrigation farming reaches its hi development in connection with intensive farming. Proper i tion will also provide a more favorable moisture content i soil.

In general the lands of the entire project are shallow and s The climatic limitations coupled with the medium supply of food makes the project a second class irrigation proposition about eighty acres would be needed to make a good living modest profits. It is imperative to the permanent success of i tion farming in this whole irrigated region, that a careful s of crop rotation, including feeding livestock and applicatio manure to the land, be established.

POWER POSSIBILITIES

A power survey of Deschutes River was completed in 191 the U. S. Geological Survey, in cooperation with the State report of the results of the survey and subsequent studies has published as Water Supply Paper 344 of the U. S. Geological vey. The construction of any or all the irrigation units herein posed will not materially affect power projects advanced i power report on the lower river, because the present summer of upper Deschutes River was already largely appropriated a time of the investigations and is, to a great extent, now in use for irrigation. The river discharge for the non-irrigating son which it is proposed in this report to use for irrigation by st comes, for the most part, at a time of the year when there is plus in the lower river, under any probable development.

It is therefore not considered necessary to discuss the effect irrigation herein proposed will have on the lower river projects, further than to call attention to the fact that the irrigation development proposed, will take all the non-irrigating son flow above the mouth of Crooked River, in addition to th the irrigation season heretofore appropriated by earlier project requiring storage.

It might also be added that seepage returns to the river wha their amount, will be greater under the full irrigation develop proposed, than those resulting from the diversion of summer only, a condition which will obtain with complete developme projects by the Central Oregon Irrigation Company and

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using no storage. How much the increased seepage may be, cannot be foretold, but it is probable that it will be such as to increase the minimum flow on the lower river, over what it would be, were the summer flow only of the upper river diverted.

Between the proposed Benham Falls reservoir and Bend, there is a total fall in the river of about 500 ft. With full irrigation development of upper Deschutes River, it is estimated there will be a maximum discharge of nearly 5,000 second feet from Benham Falls reservoir during the irrigating period, and approximately 330 second-feet discharge for domestic supply during the remainder of the year. Considering the latter, there will be available for power development at Benham Falls, Dillon Falls, Lava Island Falls, and also in one below the latter, a head of not less than 100 ft. per mile of canal. The heads and approximate lengths of canal for these four sites are given below:

Benham Falls	4,000 ft. canal,	100 ft. head
Dillon Falls	2,000 ft. canal,	65 ft. head
Lava Island Falls	5,000 ft. canal,	100 ft. head
Lower site	5,000 ft. canal,	110 ft. head

For the four sites this shows a total available head of 375 feet. With 330 second feet flow at the two upper sites and 300 at the two lower sites, the continuous power available will be in excess of 10,000 E. H. P. and with a daily variation that would not interfere with lower use, might easily accommodate peak loads of 20,000 E. H. P.

The cost of development would not be greatly different per horse power for the different sites, and for combined development of 10,000 H. P. at the four sites, the total cost would be approximately $70.00 per horse power divided about equally between the cost of diversions, canals, flumes and penstocks, and the cost of equipment and power houses.

With the use of water as assumed for irrigation, there would be available during irrigating season, the following combined amounts of power.

May	80,000 H. P.
June	95,000 H. P.
July	120,000 H. P.
August	95,000 H. P.
September	40,000 H. P.

If a complete development were provided for the July flow, the unit cost would be reduced to approximately $40.00 per horse power, with less than one-third of this amount in the cost of diversions, canals, flumes and penstocks. If a proper market were available for irrigation pumping, the development of this power would appear especially attractive.

There is a possibility that pumping will be economically desirable for a John Day Project, with a use of from 40,000 to 60,000

H. P. and it was considered in this connection. The greater length of irrigating season for that district, and the desirability of storing water in a reservoir near the irrigable land, to reduce the size of the long supply canal to a minimum, make a continuous power supply so much more attractive that the long transmission distance of about 140 miles apparently eliminates that field. A storage supply from Crooked River may be found more feasible for the area around Prineville than an Ochoco Creek supply, and in such case a pumping lift of from 100 to 150 feet, for from 10,000 to 20,000 acres, would save many miles of costly canal. A lift of 150 feet for 15,000 acres of land would require about 4,500 H. P. A transmission line from Benham Falls to Prineville to carry this power would probably cost about $2,000 per mile or about $80,000; with a pumping plant estimated at $100,000, the power and pumping alone would cost more or less than $30.00 per acre, depending on which power development were adopted; to this would have to be added storage, distributing, and operating costs. The above is therefore a possible market but cannot be regarded as very attractive.

Electrically operated pumps may possibly play an important part in lifting water from shallow wells in the upper Willamette Valley. It is scarcely probable, however, that the ultimate area thus served will exceed 100,000 acres. With an average lift of 25 feet and a supply of 1 sec. ft. to 100 acres, a power line capacity of but 5,000 H. P. would be needed. The cost per horse power for transmission line could hardly, with that small amount, be less than $40 per H. P., which would bring the cost to $200,000 for a 90 mile line from Benham Falls almost due west to Eugene. Such a unit cost for transmission would prevent a Benham Falls plant from competing with power sites, nearer the lands in question.

The ultimate future development of Harney Valley will probably necessitate electric pumping for an area of from 50,000 to 100,000 acres. With an average lift of 30 feet this would call for 3,000 to 6,000 H. P. and with a cost for transmission line of $3000 per mile, the 120 miles line required would result in a transmission cost of $60. per H. P. for even the larger amount. This cost is excessive, and unless other use for additional power could be found in that district to reduce the unit transmission charge. it is evident that Harney Valley cannot be considered as a market for Deschutes power.

Following are some line distances from Benham Falls to towns:

	Miles.		Miles.
Prineville	38	Silver Lake	58
Madras	52	Klamath Falls	160
McDonald	120	Eugene	86
Umatilla	170	Salem	108
Burns	120	Portland	128

It is probable that in years to come, a market for at least the ten to twenty thousand continuous horse power will develop, and it is therefore a remote asset to the state; but it does not appear that any present value can be attached to the power features for the purpose of the estimates submitted herein.

CONSTRUCTION, DESIGNS AND ESTIMATE OF COST.

Special attention is called to the fact that the estimates in this report are to be regarded as advance or preliminary estimates of cost only. They are, nevertheless, founded on good field investigation and careful office computation, and may be considered a reasonably safe guide in determining future policies to be followed with respect to development of the water resources of this basin.

The estimates should not, however, be construed as indicative of any estimated costs that may be announced by the Secretary of the Interior through the public notice rquired by Section 4 of the Reclamation Act of June 17, 1902, (in advance of any construction by the Government.)

Attention is called to the fact that the figures given are merely the first cost, or actual disbursements estimated as necessary to build the work. No allowance has been made for interest, discounts or sinking fund.

BENHAM FALLS RESERVOIR AND DAM DESIGN.

A first impression at Benham Falls is that the proper location for a dam is at the head of the Falls. Closer examination however reveals the fact that the river has in quite recent geologic times, been pushed over to the place it now occupies, from some place east of its present location, by successive lava flows which at the same time have raised the river bed some several hundred feet. The latest movement seems to have been due to the lava flow from Lava Butte, which raised and crowded the river toward and through a gap in the older geologic formation, which now shows along the west side of the river for several miles above and below Benham Falls.

Borings show that a masonry dam is not practicable anywhere in this vicinity, and a loose rock and earth fill dam, located at site A (Sheet No. 21), proves to be the most economical.

It has been shown that the storage capacity required at Benham Falls reservoir, on the assumptions made as to seepage and evaporation losses, and with no provision for carry-over storage from years of low run-off to years of high run-off, is in round numbers 395,000 acre feet. The maximum elevation of water surface for this storage is 4197.0 feet and the area flooded is approximately 18,000 acres.

The dam as designed provides for an excess storage of 47,500 acre feet, with spillway crest at elevation 4200.0 feet and total terial in excavation was made from surface examination only, the canal sections being comparatively shallow.

ESTIMATED COST.

Excavation, earth	210,400 cu. yds.	@ $0.25	$ 52,600
Excavation, rock	117,700 cu. yds.	@ 1.10	129,470
Concrete canal lining (1 to 1 side slopes)	5,000 cu. yds.	@ 7.50	37,500
Concrete canal lining (½ to 1 side slopes)	200 cu. yds.	@ 8.75	1,750
Concrete structures	1,100 cu. yds.	@ 1.50	16,500
Steel reinforcement	72,000 lbs.	@ .05	3,600
Concrete pipe, reinforced, 28 in. diameter in place @ $2.80			3,290
Highway bridges, 4 @ $150			600
Turnouts, 110 sec. ft. 1			290
Turnouts, 30 sec. ft. 1			72
Turnouts, 15 sec. ft. 2 @ $96.50			193
Wasteway at mile 5.1			575
Wasteway at mile 11.3			5,340
Wasteway at Little Falls			500
Culverts, 5 @ $200			1,000
Telephone line, 25 miles @ $250, including patrol houses			6,250
Wire fence, 5 wire, 42 miles @ $125			5,250
Distributing system, 20,325 acres at average cost of $9.80 per acre			199,185
Headgates at Aubrey Falls diversion weir			900
Drainage @ $1.00 per acre			20,325
Right of way, land improvement, etc.			3,500
			$488,690
Engineering and administration, 25 per cent			122,310
			$611,000

The total estimated cost of the proposed West Side Unit, to irrigate 20,325 acres, is as follows:

Storage and water rights	$188,500
Aubrey Falls diversion dam, part	32,000
Canals and distributing system	611,000
	$831,500

Estimated cost per acre, $40.91.

A West Side Unit, to irrigate approximately 15,000 acres has been proposed and described in Bulletin No. 2 Deschutes River Projects. This Bulletin is incorporated in the present report Pages 74 to 86 inclusive and estimated cost of this smaller project is given on Page 83.

NORTH UNIT—CANALS AND DISTRIBUTING SYSTEM.

The North Unit is planned to irrigate 99,300 acres. In general, the natural slope of the ground over which the canal systems for the North Unit pass, is such that it is possible to transport the water at a very high velocity, permitting therefore, a canal of relatively small cross section. For this reason, all of the main canals and a large part of the distributing laterals have been designed to be concrete lined. See Sheets No. 58 to 65 for sections proposed.

Open test pits were dug throughout the main canal line from Aubrey Falls diversion site to Agency Plains, at approximate inter-

No allowance is provided in the estimate for changing of Oregon Trunk railroad location or purchase of right of way lands other than as above.

CRANE PRAIRIE RESERVOIR AND DAM DESIGN.

The type of dam proposed for Crane Prairie Reservoir is similar in general to that proposed for the Benham Falls Reservoir. An outlet control using stop logs is planned instead of the sluice gate control proposed at Benham Falls, as the maximum depth of water above the bottom of the outlet channel will be only 35 feet. See sheet No. 67.

All of the lands within the site of the proposed Crane Prairie Reservoir remain unpatented and may therefore be acquired from the federal authorities without cost if used for the purposes of irrigation. The right to compare the cost of storage in the Crane Prairie Reservoir, on this basis, with that at Benham Falls, from the point of view of social economy may be questioned. However, such appears to be the price at which the water users may obtain the necessary storage and the estimates of cost of storage herewith submitted are made on this basis.

CRANE PRAIRIE RESERVOIR AND DAM—ESTIMATED COST

Dam—				
Diversion channel and spillway—				
Excavation, rock	18,000 cu. yds.	@ $ 1.50	$27,000	
Excavation, rock	1,000 cu. yds.	@ 1.25	1,250	
Concrete lining	300 cu. yds.	@ 12.25	3,675	
Concrete gates and spillway	550 cu. yds.	@ 14.50	7,975	
Steel reinforcement	2,000 lbs.	@ .06	120	
Stop logs, hoists, railings and miscellaneous			1,745	
				$ 41,765
Embankment—				
Earth stripping	2,500 cu. yds.	@ $ 0.50	$ 1,250	
Earth excavation	1,000 cu. yds.	@ 0.25	250	
Earth haul (½ mile)	30,000 cu. yds.	@ 0.50	15,000	
Earth puddling	31,000 cu. yds.	@ 0.20	6,200	
Rock haul (diversion channel)	20,500 cu. yds.	@ 0.50	10,250	
Rock haul, spillway	1,500 cu. yds.	@ 0.25	375	
Riprap paving	7,000 cu. yds.	@ 2.50	17,500	
				$ 50,825
Cofferdam and trestle work			$ 400	
Roads, 5 miles @ $500			2,500	
Construction bridge			400	
Building, temporary, 3 @ $500			1,500	
Building, permanent, 1			2,000	
Telephone line to La Pine, 20 miles @ $100			2,000	
				$ 8,800
Puddling reservoir along east side				20,000
				$121,390
Engineering, administration and contingencies, 25 per cent				30,610
				$152,000

WATER POWER RIGHTS—ESTIMATED VALUES.

There are a number of rights, some developed or partly developed, but the majority undeveloped, between Bend and the mouth of the river. No attempt has been made to appraise these individually nor will any estimates of the cost of damage to any undeveloped plant be stated.

For purposes of this estimate, and only to insure that all matters of expense and damage have been sufficiently covered, an allowance of $300,000 has been made for all damage of this description from Benham Falls to the mouth of the river.

COST PER ACRE-FOOT OF WATER AT DIVERSION POINTS.

It has been noted that, for the projects proposed, with the assumptions as to duty of water, reservoir and canal losses, and prior water rights, there would be a deficiency of about 2 per cent in the mean annual run-off at Benham Falls.

The cost of water per acre-foot herein used is based upon neither the maximum nor minimum run-off and not exactly upon the mean run-off—but upon the assumed annual demand of water at diversion by the projects proposed, which together with the assumed prior water use, is approximately 2 per cent greater than the mean annual run-off of Deschutes River; the cost of storage is distributed to the several proposed units in proportion to the water diverted to each.

The total estimated cost of water at diversions is as follows:

Crane Prairie reservoir	$ 152,000
Benham Falls reservoir	991,000
Power and other affected rights	300,000
Total	$1,443,000

Total estimated amount to be diverted 614,400 acre-feet. Cost per acre-foot at diversions $2.35.

The estimated cost of water at diversion for the West Side, North and South Units, is as follows:

	Diversions, acre-feet.	Cost.
West Side Unit	80,200	$ 188,500
North Unit	317,500	745,500
South Unit	216,700	509,000
Total	614,400	$1,443,000

AUBREY FALLS DIVERSION DAM.

See Sheet No. 42. Under West Side Unit, "Investigations for this report," was discussed the location of a diversion site for the West Side Unit, to serve at the same time for North Unit diversion. The site referred to as Aubrey Falls diversion site was selected for these plans and estimates after test borings had been made at both this site and that at Swalley Bridge.

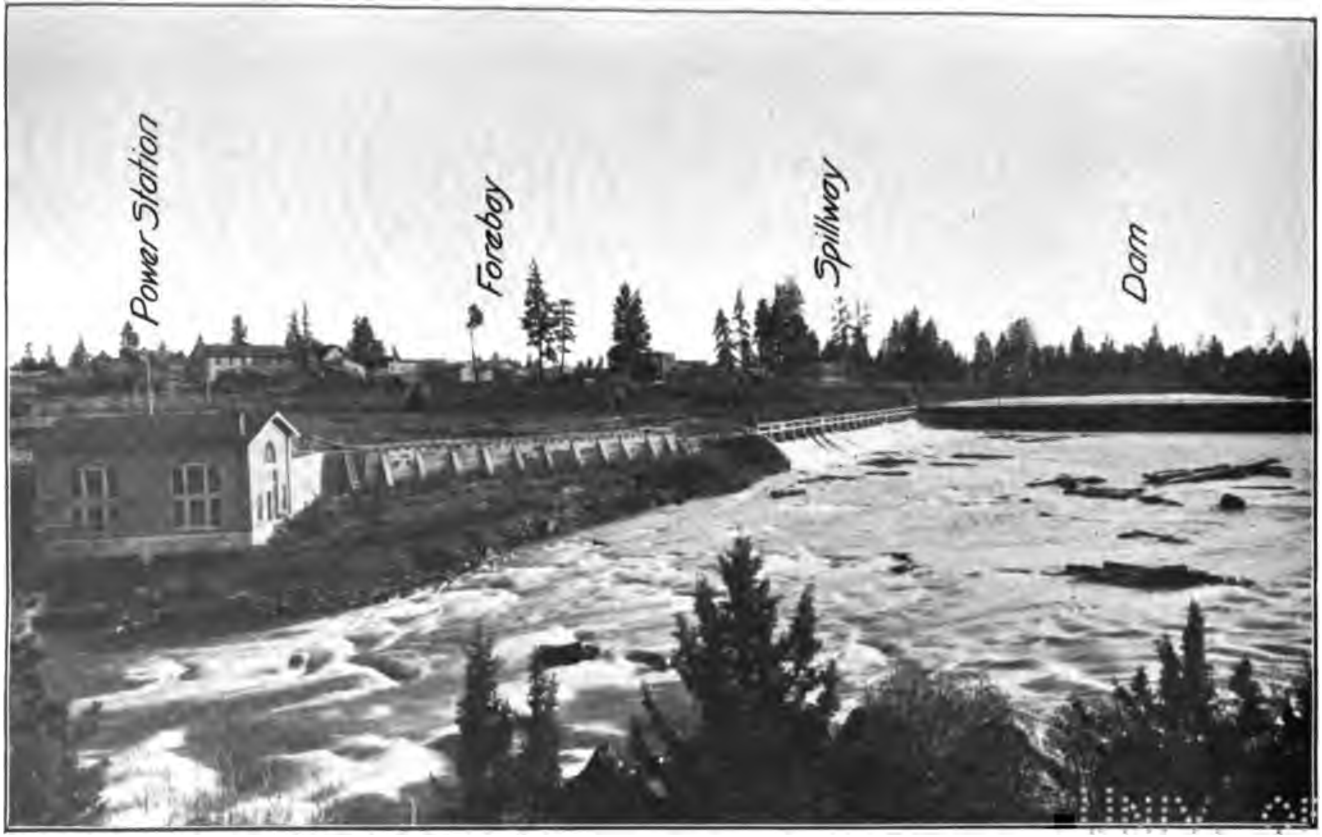

Plate XVI.

Bend Power Plant, showing Two Units completed.

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From Mile	Elev	to Mile	Dist Miles	per Mile
3.70	[illegible]	4.17	0.47	24000
4.17	[illegible]	4.75	0.58	14000
4.75	3147.5	5.15	0.40	20,000
	3146.[illegible]			
5.15	3146.5	5.28	0.13	65,000
5.28	[illegible]	6.30	1.02	22,500
6.30	3136.[illegible]	6.45	0.15	15,000
6.45	3136.[illegible]	6.53	0.08	22,000

From Mile	Elev	to Mile	Dist Mile	Cos per Mile	i
6.53	[illegible]	7.78	1.25	[illegible]	
7.78	[illegible]	9.11	1.33	12,000	
	[illegible]				
9.11	[illegible]	9.26	0.15	21,000	
9.26	[illegible]	9.31	0.05	58,000	
9.31	[illegible]	9.39	0.08	22,000	
9.39	[illegible]	9.86	0.47	[illegible]	
	[illegible]				
9.86	[illegible]	10.05	0.19	20,000	

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From Mile	Elev	to Mile	Dist Miles	Cost per Mile
10.05	3122.2	10.18	0.13	15,000
	3122.5			
10.18	3121.5	10.43	0.25	21,000
10.43	3118.2	10.53	0.10	18,000
10.53	3118.3	11.67	1.14	11,000
11.67	3116.5	12.14	0.47	12,000
	3115.5			
12.14	3114.8	12.42	0.28	19,000
12.42	3112.5	13.67	1.25	13,600

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From Mile	Elev	to Mile	Dist Miles	Cost per Mile	Tot
1367	3109.2	1433	066	16,000	1 9
1433	3108.5	1480	047	12,000	4
1480	3107.5	1535	045	9,000	4
1535	3106.2	1537	002	20,000	4
1537	3099[illegible]	1660	133	7,000	9,3
1660	3095[illegible]	1670	010	50,000	5,4
1670	3080[illegible]	1827	157	7,000	10,9

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From Mile	Elev.	to Mile	Dist. Miles	Cos
				per Mile
18.27	[illegible]	19.45	1.18	6500
19.45	[illegible]	19.53	0.08	16,000
19.53	[illegible]	20.06	0.53	5600
20.06	[illegible]	20.17	0.11	20,000
20.17	[illegible]	20.40	0.23	5600
20.40	[illegible]	20.51	0.11	20,000
20.51	[illegible]	21.12	0.61	3000

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vals of a mile. Between these pits, either earth augur holes were put down to rock, or soundings were made with steel sounding rod at irregular intervals of about a thousand feet. The main canal and main lateral system for this entire unit, from Aubrey Falls diversion to Agency Plains, and to Round Butte, are designed to be concrete lined. The 18 miles, from Deschutes River to Crooked River crossing, lends itself admirably to this design, the slope of the land being such that an average velocity of 10 to 12 ft. per second can be maintained.

From the Aubrey Falls diversion to the Crooked River crossing, no difficult construction is encountered. This section of canal however will be unique in that it will carry a volume of water approximately equal to the entire water flow of the present Deschutes River at this point, and at an average velocity of 12 ft. per second. For the Crooked River crossing, a grade crossing appeared most economical, and the plan contemplates a reinforced concrete aqueduct supported upon a steel arch bridge similar to the present Oregon Trunk R. R. Bridge. The first five miles of canal beyond Crooked River, will be expensive to construct, as there is about one mile of tunnel and 0.41 miles of reinforced concrete flume, while the remainder is canal located on a steep side hill. The slope of this canal section is relatively flat, as it was necessary to hold up the grade in order to pass controlling points. North from this point, the main canal continues on a relatively steep grade.

The main lateral to Round Butte, which takes out at mile 36.8, will serve not only the lands west and north of Round Butte and extending to Willow Creek Canyon, but also other lands south of Round Butte. A lateral from mile 46.6 will serve lands about the town of Metolius. At mile 50, the main canal crosses Willow Creek by a pipe line and continues northwest to Agency Plains, which it reaches over an aqueduct from mile 59.62 to 59.90, and through a pipe line from mile 60.25 to 61.28. At mile 57.7, a lateral takes out from the main canal and continues east across Mud Springs Creek to serve the lands lying between Mud Springs Creek and Hay Creek.

The estimated cost of construction of the canal and distributing system for the North Unit is as follows:

Concrete canal lining	42,000 cu. yds.	@ 8.50	357,000
Concrete Pilot Butte Canal crossing, reinforced	27 cu. yds.	@ 12.00	324
Railway crossing, additional			500
Wasteways, 2 @ $2,000			4,000
Culverts, 6 @ $300			1,800
Telephone line, including patrol house, 18 miles @ $250			4,500
Bridges, 15 @ $250			3,750
Wire fence, 5 wire, 36 miles @ $125			4,500
Right of way			5,700
Diversion, 6 sets of sluice gates @ $450			2,700
			$622,874
Engineering and administration, 25 per cent			155,126
Total cost, Aubrey Falls diversion weir to Crooked River			$778,000

CROOKED RIVER, NORTH TO LANDS.

Crooked River Crossing, steel arch, bridge and concrete flume			$104,176
Open cut excavation, earth	650,000 cu. yds.	@ $ .20	130,000
Open cut excavation, hardpan	246,000 cu. yds.	@ .50	123,000
Open cut excavation, rock	370,000 cu. yds.	@ 1.10	407,000
Tunnels, 4800 lin. ft. excavation @ $22.00			105,600
Tunnels, 4800 lin. ft. concrete lining, 6,000 cu. yds. @ $12.00			72,000
Tunnel portal	72 cu. yds.	@ $10.00	720
Canal lining, concrete	109,500 cu. yds.	@ 8.50	930,750
Flumes, concrete, reinforced	6,269 cu. yds.	@ 12.00	75,228
Flumes, concrete, unreinforced	275 cu. yds.	@ 9.00	2,475
Willow Creek Crossing, 2-60-inch steel pipes			45,000
Round Butte pipe line, reinf. concrete, 46-in. diam			17,500
Agency Plains pipe line, steel and reinf. concrete			72,000
Mud Springs pipe line			15,000
Main turnouts, 4 @ $350			1,400
Small turnouts, 15 @ $200			3,000
Culverts, 14 @ $300			4,200
Wasteways, 5 @ $2,000			10,000
Wasteways, 2 @ $800			1,600
Telephone line, incl. patrol houses, 50 miles @ $250			12,500
Railway crossings, 2 @ $500			1,000
Bridges, 20 @ $300			6,000
Bridges, 10 @ $150			1,500
Distributing system, 99,300 acres @ average cost of $8.38 per acre*			832,134
Drainage			99,300
Wire fence, 5 wire, 86 miles @ $125			10,750
Right of way			10,000
			$3,093,833
Engineering and administration, 25 per cent			773,167
Total cost Crooked River to land			$3,867,000
Total cost Aubrey Falls Diversion Weir to land			$4,645,000

*This cost per acre is derived from a number of differing costs for different sections.

From Mile	Elev.	to Mile	Dist. Miles	per Mi
0	31582	085	085	46,0
085	31565	129	044	1880
129	31546	379	250	570
379	31472	383	004	440
383	31446	511	128	36,0
511	31438	713	202	430

Explanation of Func

"Q" is rate of flow in
"A" is area of water
"r" is mean hydrau
"v" is velocity of f
"s" is slope of cond
"n" is coefficient of

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From Mile	Elev	to Mile	Dist Miles	Cost	
				per Mile	Tot
7.13	[illegible]	7.15	0.02	40,000	
7.15	[illegible]	7.58	0.43	35,000	[illegible]
7.58	[illegible]	8.91	1.33	39,000	[illegible]
8.91	[illegible]	8.93	0.02	33,000	
8.93	3067.3	9.06	0.13	29,000	[illegible]
9.06	3062.5	12.50	3.44	37,500	12
12.50	3030.3	13.60	1.10	30,000	33
13.60	3009.3	13.62	0.02	30,000	
13.62	3006.5	14.21	0.59	24,000	14

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From Mile	Elev	to Mile	Dist. Miles	Co
				per Mile
14.21	2981.5	15.15	0.94	28,000
15.15	2961.3	16.36	1.21	43,000
16.36	2950.3	16.38	0.02	34,000
16.38	2946.4	16.66	0.28	28,000
16.66	2935.5	17.20	0.54	35,000
17.20	2928.8	18.27	1.07	29,000
18.27	2896.9	18.35	0.08	

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From Mile	Elev.	to Mile	Dist. Miles	Cost	
				per Mile	Tot
18.35	2893.3	18.52	0.17	135,000	22
18.52	2892±	19.68	1.16	40,000	46
19.68	2886±	20.10	0.42	150,000	63
20.10	2881.2	20.29	0.19	244,000	46
20.29	2879.5	21.01	0.72	66,500	47,
21.01	2876.5	21.46	0.45	244,000	109
21.46	2871.2	21.54	0.08	135,000	10,8

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From Mile	Elev	to Mile	Dist Miles	Cost per Mile	To
21.54	2870.[illegible]	21.77	0.23	111,000	
21.77	2868.[illegible]	21.83	0.06	135,000	
21.83	2867.[illegible]	21.96	0.13	130,000	
21.96	2866.[illegible]	22.01	0.05	135,000	
22.01	2865.[illegible]	22.11	0.10	44,000	
22.11	2865.[illegible]	22.16	0.05	135,000	
22.16	2864.[illegible]	22.54	0.38	47,000	

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from Mile	Elev	to Mile	Dist Miles	Cost per Mile	Tota
50.02	2777.5	50.16	0.14		54,0
50.16	2748.9	58.73	8.57	34,500	295,7
58.73	2721.5	58.74	0.01	39,000	39
58.74	2709.2	58.87	0.13	27,000	35
58.87	2675.5	59.28	0.41	16,000	6,56
59.28	2648.1	59.94	0.66	13,000	8,5
59.94	2615.5	60.26	0.32	72,000	23,0
60.26	2594.5	60.57	0.31	14,000	4,34

From Mile	Elev	to Mile	Dist Miles	Cost	
				per Mile	Total
50.02	2777.2	50.16	0.14		59,0
50.16	2748.6	58.73	8.57	34,900	295,7
58.73	2721.5	58.74	0.01	39,000	39
58.74	2709.2	58.87	0.13	27,000	35,1
58.87	2675.5	59.28	0.41	16,000	6,56
59.28	2648.1	59.94	0.66	13,000	8,5
59.94	2615.5	60.26	0.32	72,000	23,0
60.26	2594.5	60.57	0.31	14,000	43,4

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TOTAL ESTIMATED COST.

The total estimated cost of the proposed North Unit, to irrigate 99,300 acres is as follows:

The total estimated cost of the proopsed North Unit, to irrigate 99,300 acres, is as follows:

Storage and water rights	$ 745,500
Aubrey Falls Diversion, part	129,000
Canals and Distributing system	4,645,000
	$5,519,500

Estimated cost per acre, $55.58.

SOUTH UNIT—CANALS AND DISTRIBUTING SYSTEM.

The South Unit is planned to irrigate 48,460 acres of land. The diversion dam, which is located at Lava Island Falls, will raise the water only 8 feet, or sufficient to regulate the supply into the canal. (See sheet No. 23). The plans contemplate the location of the headgates for the Arnold Ditch at this diversion. The bed of the river at this point appears to be solid rock and as the structure is low and its cost relatively small, no test borings were made at this site.

LAVA ISLAND DIVERSION WEIR—ESTIMATED COST.

The estimated cost of the Lava Island Diversion Weir is as follows:

Temporary diversion and control, say		$ 2,500
Excavation, 500 cu. yds. @ $1.50,	$ 750	
Excavation, 500 cu. yds. @ 3.50,	1,750	2,500
Concrete, 900 cu. yds. @ $12.00		10,800
Gate keeper's house and stable		2,500
Hand railings, steps, stop logs and miscellaneous		1,200
		$ 19,500
Engineering, administration and contingencies, 25 per cent		4,500
		$ 24,000

The canal line for the proposed South Unit is planned to be partially earth lined and partially concrete lined, the 30 miles from the diversion to the Dry River Bed crossing being practically all concrete lined, while the remainder is practically all earth lined canal. See Sheets No. 52 to 57 inclusive. At the Dry River Bed a pipe line crossing is used. At mile 35, a drop is utilized to avoid an expensive crossing over a dry canyon. At mile 43.6 the main canal drops down approximately 100 feet, while a lateral continues northward from the head of the drop for about 7 miles. At mile 46.5 the main canal drops about 30 feet, in order to obtain more favorable location; it then continues north to the pass southeast of Powell Buttes, with laterals extending from this point around Powell Butte.

The cost of construction on this unit will be relatively high, because of the long distance from railroad connection; because of the absence of water and the consequent necessity of transport-

No test pits were dug for classification of material for canals of this unit. The Arnold Ditch parallels the location for the first 10 miles, and furnishes a very fair basis for classification of material, from diversion to the lava beds just west of Dry River. It is believed the classification used throughout is conservative. By far the larger part of the main canal is designed to be concrete lined. Very little land under this unit is served, west of the Dry River Bed, approximately 32 miles from the diversion.

MAIN CANAL AND DISTRIBUTING SYSTEM—ESTIMATED COST.

Excavation, earth	578,390 cu. yds.	@ $ .22		$ 127,246
Excavation, rock	485,970 cu. yds.	@ 1.25		607,462
Concrete canal lining	1,008 cu. yds.	@ 10.80	$ 10,886	
Concrete canal lining	16,733 cu. yds.	@ 10.50	175,697	
Concrete canal lining	40,345 cu. yds.	@ 9.00	363,105	
Concrete canal lining	8,918 cu. yds.	@ 8.00	71,344	621,032
Concrete drop at mile, 43.6, incl. turnout				6,000
Concrete drop at mile, 46.5, incl. turnout				8,000
Dry River Bed pipe crossing, steel pipe				14,960
Wasteways				5,000
Highway bridges, 20				7,500
Culverts, 2 @ $500				1,000
Overhead waterways, 50 @ $40				2,000
Telephone line, 61 miles @ $250, incl. patrol houses				15,250
Wire fence, 5 wire, 120 miles @ $125				15,000
Roads, 28 miles @ $500				14,000
Drainage				50,000
Sluice gates and hoists, Lava Island Diversion				2,500
Distributing system, 48,460 acres @ $8.53 per acre, average				413,364
Right of way				6,000
				$1,916,314
Engineering and administration, 25 per cent				479,686
				$2,396,000

TOTAL ESTIMATED COST.

The total estimated cost of the proposed South Unit to irrigate 48,460 acres is as follows:

Storage and water rights	$ 509,000
Lava Island Diversion	24,000
Canals and distributing system	2,396,000
	$2,929,000

Estimated cost per acre, $60.44.

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42.09	[illegible]	43.51	1.42	8.00
43.51	[illegible]	44.40	0.89	8.00
44.40	[illegible]	45.54	1.14	6.00
45.54	[illegible]	46.62	1.08	6.00
46.62	[illegible]	47.19	0.57	6.00
47.19	[illegible]	47.38	0.19	
47.38	[illegible]	47.86	0.48	19.00
47.86	[illegible]	49.19	1.33	19.00
	[illegible]			

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From Mile	Elev.	to Mile	Dist. Miles	Co
				per Mile
49.19	3502.2	52.14	2.95	26,000
52.14	3539.8	53.67	1.53	24,000
53.67	3527.2	54.54	0.87	26,000
54.54	3502.3	55.90	1.36	26,000
55.90	3508.2	56.09	0.19	10,500
56.09	3508.2	58.36	2.27	5,000
58.36	3506.9	61.77	3.41	6,000

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OPERATION AND MAINTENANCE.

Strictly speaking, operation and maintenance should include only the labor and supplies necessary to operate the irrigation system economically, and maintain it in as good condition as when first constructed. The line between what is operation and what is maintenance is not always clear. For example, it is necessary for the man or men who open, regulate and close gates at the many turnouts along main canals and main laterals, to ride or go from one gate to another. While doing this they watch the ditches for any new leak, threatened break, accumulation of weeds and drift, or other of the many troubles encountered in canal operation, and either correct the troubles at the time, or telephone a report on them from the nearest telephone patrol box, to the superintendent. These men are customarily called ditch riders. The actual operation of opening and closing gates is clearly operation; the repairing of leaks, removal of weeds from canal, etc. is clearly upkeep or maintenance; but the time spent in traveling from point to point on canals is properly chargeable to both; for this reason, the two subjects are invariably referred to under one combined head when relating to irrigation management.

From time to time, in the best designed and constructed irrigation systems, it is found desirable to make what are usually referred to as betterments. For illustration: if it should appear that a change in canal location costing $2000.00 and shortening the length a half mile, will reduce the cost of operation and maintenance $140.00 a year, it would be economy to make it, if interest on money is not greater than 7 per cent. It is often real economy to build cheaply in the beginning, when there is perhaps lack of confidence in the project and the interest rate is therefore high, with the expectation that when money is cheaper changes will be made. This betterment work is often done by the regular Operation and Maintenance force and is therefore, for convenience of accounting, sometimes included with or under Operation and Maintenance.

The following tabulation of Operation and Maintenance costs is from the Reclamation Service reports for 1912 on the projects partly or wholly constructed. The practice of including betterments with Operation and Maintenance has since been discontinued by the Reclamation Service.

Projects.	Irrigable acres.	Irrigated acres.	Operation.		Upkeep.		Betterments.	
			Total.	Per acre.	Total.	Per acre.	Total.	Per acre.
Arizona., Salt River......	160,000	159,170	$ 65,301	$0.41	$ 126,200	$0.79	$.........	$.....
Arizona-California, Yuma.	38,500	13,767	32,987	.85	67,729	1.76	....	......
California, Orland........	14,200	4,230	6,417	.45	6,726	.47	....	......
Colorado, Unc. Valley....	43,450	48,023	15,989	.37	36,348	.83	18,865	.44
Idaho, Boise	200,000	61,725	45,215	.23	32,093	.16	11,167	.05
Minidoka—								
Gravity	62,000	40,615	16,758	.27	18,366	.30	130,997	2.15
Pumping	47,300	29,623	35,146	.75	29,612	.63	....	......
Montana, Flathead	35,000	4,203	5,359	.15	2,511	.07	639	.02
Huntley	28,805	14,425	7,169	.25	20,976	.73	31,672	1.10
Milk River.....	7,800	352	1,256	.16	4,638	.60	11,064	1.42
Sun River......	16,346	6,824	2,547	.16	5,900	.36	1,316	.08
Montana-North Dakota, Lower Yellowstone.....	37,625	5,068	5,458	.15	92,952	2.47	29,990	.79
Neb.-Wyo., North Platte.	103,658	55,631	40,624	.17	30,700	.36	5,656	.07
Nevada-T., Carson........	52,039	36,620	15,366	.17	29,212	.32	1,014	.01
New Mexico, Carlsbad...	20,277	13,459	6,726	.33	13,443	.66	....	......
Hondo* ..	10,000	1,261	2,706	.27	1,110	.11	270	.03
New Mexico-Texas, Rio Grande Leasburg Unit	25,000	23,115	5,587	.22	1,043	.04	880	.04
N. D., N. D. Pumping								
Bu-Trenton	4,050	....	5,072	1.29	8,417	2.15	....	......
Williston Unit.........	8,190	323	6,745	.82	12,483	1.52	16,934	2.07
Oregon, Umatilla.........	17,252	4,600	9,824	.56	13,302	.77	4,014	.23
Oregon-Cal., Klamath....	30,093	23,834	6,462	.21	7,576	.25	6,580	.22
South Dakota, Belle F...	65,868	27,897	10,206	.15	23,449	.36	25,256	.38
Washington, Okanogan...	9,900	7,260	7,402	.74	5,351	.53	845	.08
Yakima-Sunnyside	80,076	55,800	34,019	.42	52,461	.66	....	......
Tieton	34,613	15,008	18,040	.52	21,565	.62	....	......
Wyoming, Shoshone......	41,332	16,524	16,576	.40	7,085	.17	120,427	2.91
Totals	1,193,374	641,397	424,957	$ .36	671,248	.56	417,586	.85

General: The term irrigable designates the area that the service can supply with water.

Ariz.—Salt River: Area includes entire valley. Water delivered based on estimate of 3.52 acre-feet delivered to land for year ending May, 1912.

Ariz.—Cal.—Yuma: Costs include operating of three pumping plants.

Cal.—Orland: Area irrigated includes town lots aggregating 170 acres.

Colo.—Uncompaghre Valley: Area irrigated includes the entire valley. Costs and water delivered are for the 27,887 acres irrigated directly by the Service. In addition, 4,513 acres under private canals were supplied with Gunnison water, and 15,623 acres were under private canals without Gunnison water.

Idaho—Boise: Area includes 18,000 acres irrigated under contracts with private companies, and includes 315 contracts. Water delivered to farms on rental contracts, 78,775 acre-feet, or 1.8 per acre; water delivered to private companies, 40,473 acre-feet, or 2.25 per acre.

Idaho—Minidoka: Cost of drainage work included in betterments. Water reported was that delivered to heads of laterals. Canal mileage is exclusive of drains.

Mont.—Huntley: Cost of betterments includes $26,173 for drainage construction.

Nev.—Truckee—Carson: Area irrigated under rental contracts, etc., includes 11,561 acres under unsettled vested water rights. Cost per acre irrigable area is based on 90,700 acres, part of which is supplied with flood water.

N. Mex.—Hondo*: Costs per acre irrigable area are based on 10,000 acres, the estimated area of completed project.

N. Dak.—N. Dak. Pumping: No water was pumped on the Buford-Trenton unit.

Ore.—Cal.—Klamath: Area under water rental contracts includes 1,771 acres under vested water rights.

Wash.—Okanogan: Area irrigated under rental contracts includes 1,350 acres under vested water rights.

Wash.—Yakima-Sunnyside Unit: Area irrigated under contract includes Washington Irrigation Co., and Kennewick water rights.

It is seen that the mean cost of operation, upkeep (maintenance) and betterment, per acre irrigable, was $0.36, $0.56 and $0.35, respectively, and that the mean total cost of Operation and Maintenance (including betterment) was $1.27 per acre irrigable. It should be noted that in most cases the irrigable land is in excess of that actually irrigated. This is because many of the projects are new and all the land is not yet cultivated. A little more than half the total area irrigable was actually irrigated at that time, and if the entire cost of Operation and Maintenance were charged to the irrigated area, the acre cost of Operation and Maintenance would be almost double that given in the table. While the total operation and maintenance cost would be somewhat greater if the entire irrigable area were irrigated, the difference in most projects would be small because all the main canals and main laterals at least are operated, and generally, most of the sublaterals for the areas given as irrigable. It must also be borne in mind that many of these projects are still in their early years, when the maintenance of the new canals and ditches is much more expensive than in later years. Each successive year of the projects in operation has shown a decreased cost of operation and maintenance. and it may be expected that the mean cost, in time, will be reduced to $1.00 per acre or even less.

For the Deschutes Project proposed in this report, the larger canals are designed to be concrete lined and all the structures, except the smaller farm turnouts, to be of concrete or metal. The maintenance water supply, as well as during the irrigating season in full. This increased cost of operation might be as much as 25c per acre, making a total cost of 60c per acre for operation alone. If the upkeep of maintenance can be reduced to 40c per acre the true operation and maintenance will then be $1.00 per acre. It does not seem unreasonable to expect that this figure may be reached in time. To this would be added the cost of whatever betterments are found desirable or necessary, if cost of betterments are included in Operation and Maintenance.

SUMMARY AND CONCLUSIONS.

SUMMARY

1. Oregon Cooperative Work investigations are made by the United States Reclamation Service and the State of Oregon acting in cooperation. The work has been carried on under an agreement published in full herein.

2. Funds for conducting the work are provided in an appropriation of $50,000 by the State of Oregon and an allotment of an equal amount by the Secretary of the Interior from the Reclamation fund.

3. The purpose of the work is "to provide for detail surveys and investigations of the water resources of the State of Oregon" with particular reference to irrigation and power possibilities.

4. This report has reference only to the Upper Deschutes River basin and does not include Crooked River drainage.

5. The normal summer minimum flow of Deschutes River at Bend is approximately 1,600 second feet, with an extreme recorded minimum of 1,000 second feet January 4, 1912, and maximum recorded discharge of 4,760 second feet November 27, 1909. The mean annual run-off at Benham Falls over a period of 10 years is 1,210,000 acre feet. Approximately 20 per cent of this run-off is from Crane Prairie.

6. The area now irrigated, or for which contracts have been made with the State under the Carey Act, north of Benham Falls, is approximately 115,000 acres, for which there is available from the summer flow of Deschutes River without storage, not to exceed 450,000 acre feet of water. In addition, construction is commenced and contracts have been made with the State under the Carey Act, for approximately 30,000 acres of land south of Benham Falls, for which storage is planned in Crescent Lake.

7. Full irrigation development in this basin will require storage of the greater part of the entire remaining supply of over 750,000 acre feet.

and north of Crooked River; South Unit of approximately 48,000 acres south of the present Central Oregon canal and extending north to Powell Buttes; and an East Side Unit of 35,000 acres, consisting of the North Canal Unit of the Central Oregon Irrigation Company. A valuation of the construction already done by the Company on this last mentioned unit has been made.

9. In addition to water supply for irrigation plans and estimates, it is assumed that a domestic supply will be required throughout the non-irrigation season.

10. Duty of water is estimated at from 2.0 acre feet to 2.5 acre feet per acre at the land. The irrigation season has been estimated as from fore part of May to early in September with maximum use during month of July.

11. Storage is proposed of approximately 100,000 acre feet in Crane Prairie and 400,000 acre feet in Benham Falls reservoir. The dam for the latter is about one mile above the head of Benham Falls.

12. Agricultural or soils survey of the irrigable areas, show soils generally 16 inches or greater in depth. The physical character of soil for irrigation and cultivation is generally good, but the plant food content is frequently light, particularly in nitrogen, which will have to be added to the soil.

13. Estimated cost of Benham Falls reservoir including dam, $991.000.

14. Estimated cost of Crane Prairie reservoir and dam $152,000.

15. Estimated values of water power rights necessary to acquire for complete development of all units $300,000.

16. Estimated cost of water per acre foot at diversion points $2.35.

17. Estimated cost of Aubrey Falls diversion dam raising water 58 feet, $161,000, of which $32,000 is chargeable to West Side Unit and $129,000 to North Unit.

17½. Estimated cost of West Side Unit for 20,325 acres, $831,500 including storage, water rights and portion of diversion dam cost. Acre cost, $40.91.

18. Estimated cost of North Unit including storage, water rights, and portion of Aubrey Falls diversion dam cost, $5,519,000. Acre cost, $55.58.

19. Estimated cost of South Unit including storage, water rights and Lava Island diversion, $2,929,000. Acre cost, $60.44.

20. Drainage allowance in estimates $1.00 per acre. Not considered possible to make drainage estimates in advance of necessity for

drainage but not expected to become a serious problem at any time, for areas considered.

21. Operation and maintenance cost estimated at $1.00 per acre finally, but expected to be considerably greater during first years of operation. Betterments are not included in this figure.

CONCLUSIONS

It appears from the investigations and estimates:

1. That the water supply may be considered adequate for the irrigable areas proposed.

2. That from the standpoint of engineering and construction, all the projects may be considered as feasible within the estimated costs, but that the estimated costs here given should be appropriately increased by the addition of interest charges, or discounts, to obtain the actual cost of the work to the settler, unless the work be constructed by funds that do not bear interest, as in the case of U. S. projects built under the Reclamation Act.

3. That in considering the matter of desirability of these units or the balance of reasons for or against their construction, after taking into account all related elements of costs, and the values of the improved properties, the following deductions appear warranted:

a. That the West Side Unit for either the larger or the smaller alternative, is desirable at the estimated cost if interest on borrowed capital does not exceed 6 per cent.

b. That the North Unit, at the estimated cost, is desirable at this time, under some plan of repayment similar to that provided by the United States Reclamation Extension Act, and with interest on borrowed capital not exceeding 3 to 4 per cent.

c. That the South Unit is not desirable at the present time, but that with money that does not bear interest, as the original United States Reclamation Fund, and under the Reclamation Extension Act plan of 20 year repayments, it will doubtless prove desirable when the other units have been developed.

4. That there is a total available fall in the river between Benham Falls and Bend, of about 500 ft. of which nearly 400 ft. is available for power development in 4 separate falls of from 65 to 110 ft. each; that with the domestic water supply of 330 second feet estimated, it is feasible to develop at these falls 20,000 H. P. continuous throughout the year, with a load factor of 50 per cent; and that with the full irrigation development, it will be possible to develop approximately 100,000 H. P. at these falls, limited to the period of the irrigating season.

5. That owing to the great distance from general markets, development of the continuous power proposed between Benham Falls and Bend is not practicable and that sufficient market for the summer power proposed cannot be found, to make its development desirable.

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RECOMMENDATIONS

It is therefore recommended that for protection of the interests of the public in these projects all public land included in the areas shown on Sheet No. 164, be withdrawn for entry under the Reclamation Act. Also that all public water of Deschutes River above Aubrey Falls be withheld from such appropriation and use as may interfere with the projects herein reported as desirable for development, and that other than these no public lands or water be further withheld from entry or appropriation for this project.

LAND AND WATER WITHDRAWALS

In compliance with terms of agreement May 5, 1913, between the United States and State of Oregon, the public lands not otherwise disposed of, shown on Sheet No. 164, have been recommended to be withdrawn from entry by the Secretary of the Interior.

Lands for Benham Falls and Crane Prairie reservoir sites have been withdrawn under the first form. Irrigable lands for West Side Unit have been withdrawn under the second form.

Under date of February 28th, 1913, both the unappropriated waters of Deschutes River which may be stored in Benham Falls reservoir, and the regular flow, were withdrawn from further appropriation by the State Engineer, in compliance with agreement of May 5, 1913.

COST OF INVESTIGATIONS AND REPORT

Following is distribution and total cost of investigation to November 30, 1914. The estimated cost of completing preparation of maps and printing of report, 2,000 copies, is $1,500.00.

Summary of work and costs.	November 30, 1914	
	Paid by United States	Paid by Oregon
Stream Gauging		$ 1,460.82
Dam Site Topography, 3.6 sq. mi., Canal line run 14.7 mi. (400 ft. to 1 in.)	$ 814.00	257.75
Dam Site Borings, Benham Falls, 1426 ft.	3,253.88	4,028.79
Canal Line Investigations—		
Canal Lines run 340 mi., topography 170 sq. mi. (½ mi. to 1 in.)	4,401.43	4,078.69
Irrigable Land Investigations—		
Aneroid topography, 448 sq. mi., reconnaissance and topography, 54.5 sq. mi.	1,561.88	496.86
Investigation of Central Ore. Irr. Co. system—		
East Side unit	453.40	174.55
Diversion Site Topography—		
Aubrey Falls	161.55	13.50
Diversion Site Borings	552.34	1,074.11
Topography and Surveys, Crane Prairie Reservoir site	1,106.20	556.91
Borings and Test Pits, Crane Prairie Reservoir site	471.89	836.22
Computations, estimates and publication	1,780.14	4,209.16
	$14,556.71	$17,187.36

In addition to the above expenditures, there is also an investment by the United States, for equipment amounting to $5,188.30.

Details of Cost.

	Paid by United States.	Paid by Oregon.
Stream Gaging.		
Services, special work, by U. S. Geological Survey		$1,307.92
Office computations		152.90
		$1,460.82
Dam Site Topography, Benham Falls.		
General engineering and administration	$ 215.75	$ 35.75
Services, field work	280.85	130.94
Services, office	275.70	36.39
Supplies	....	15.88
Equipment depreciation	6.80	....
Preparatory charges	34.90	38.79
	$ 814.00	$ 257.75
Borings and Test Pits at Dam Site, Benham Falls.		
General engineering and administration	$1,245.86	$ 373.24
Diamond drill, labor	616.85	1,385.86
Diamond drill, supplies	39.48	127.04
Diamond drill equipment, depreciation and carbon loss	225.40	....
Calyx drill, labor	331.62	572.50
Calyx drill supplies	7.43	150.81
Calyx drill equipment depreciation	182.25	....
Teams and teamsters	57.70	615.83
Camp maintenance	.90	37.70
Establishing and moving camp	64.81	221.50
Cost of scow	2.15	114.60
Preparatory charges	114.85	256.60
Erecting and moving calyx drill	187.48	99.30
Erecting and moving diamond drill	177.10	73.81
	$3,253.88	$4,028.79
Canal Line Investigations.		
General engineering and administration	$1,236.38	$ 278.76
Services, field	1,461.59	1,588.20
Services, office	832.63	344.25
Supplies	67.86	120.32
Teams and teamsters	75.10	1,111.62
Camp maintenance	14.50	109.19
Equipment depreciation	137.25	....
Establishing and moving camp	190.00	338.51
Preparatory charges	33.84	86.40
Test pits	352.28	101.44
	$4,401.43	$4,078.69
Irrigable Land Investigations.		
General engineering and administration	$ 363.18	$ 39.24
Services, field	779.84	301.80
Services, office	327.20	....
Supplies	76.31	15.25
Teams	....	5.00
Camp maintenance	3.50	....
Equipment depreciation	11.85	....
Establishing and moving camp	....	4.55
Travel expense	....	39.74
Soil and agricultural investigation	....	91.28
	$1,561.88	$ 496.86

Details of Cost (Continued).

	Paid by United States.	Paid by Oregon.
Investigation Central Oregon Irrigation Co.'s Canal System—East Side Unit.		
General engineering and administration	$ 50.00	$ 25.00
Services	312.00	125.00
Travel	91.40	24.55
	$ 453.40	$ 174.55
Diversion Site Topography—Aubrey Falls.		
General engineering and administration	$ 50.00	$........
Services	73.75	2.00
Supplies	2.25	
Teams		10.00
Camp maintenance	7.75	
Equipment depreciation	8.00	
Preparatory charges	19.80	1.50
	$ 161.55	$ 13.50
Borings and Test Pits—Aubrey Falls Diversion Site.		
General engineering and administration	$ 165.00	$ 47.00
Labor	232.50	612.34
Supplies	17.68	52.71
Equipment depreciation	58.00	
Teams and teamsters		101.75
Establishing and moving camp	2.40	17.60
Camp maintenance	2.91	91.31
Preparatory charges	55.85	40.80
Erecting and moving drill	18.00	110.60
	$ 552.34	$1,074.11
Topography and Surveys, Crane Prairie Reservoir Site.		
General engineering and administration	$ 271.95	$ 27.35
Services	513.05	425.51
Supplies	17.45	4.85
Teams and teamsters	180.00	57.55
Camp maintenance and establishing	71.25	41.65
Equipment depreciation	42.50	
Preparatory charges	10.00	
	$1,106.20	$ 556.91
Borings and Test Pits, Crane Prairie Reservoir Site.		
General engineering and administration	$ 135.34	$ 37.00
Labor	132.73	296.70
Supplies	23.12	64.79
Equipment depreciation	61.50	
Teams and teamsters		108.00
Establishing and moving camp	12.00	
Camp maintenance	10.00	
Preparatory charges	60.60	96.85
Erecting and moving drill	9.60	96.30
Sinking shaft	27.00	136.58
	$ 471.89	$ 836.22
Computations, Estimates, Preparation of Data and Drawings, and Publication of Report.		
General engineering and administration	$ 806.91	$ 699.27
Services	871.45	3,379.11
Supplies	14.03	57.39
Printing	87.75	14.54
Photography		58.85
	$1,780.14	$4,209.16

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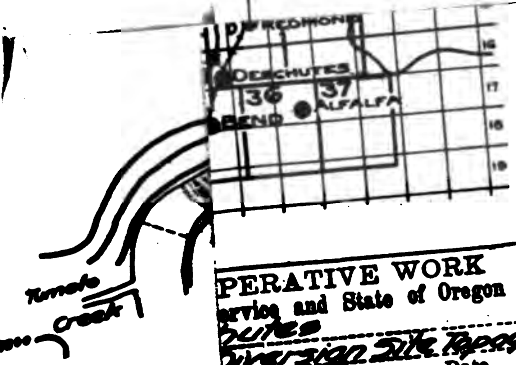

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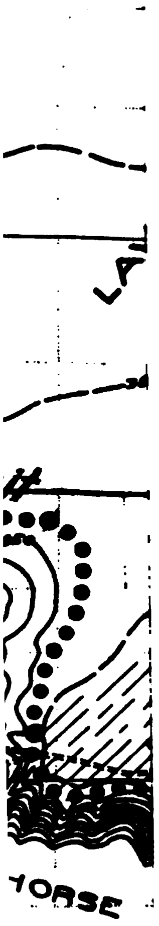
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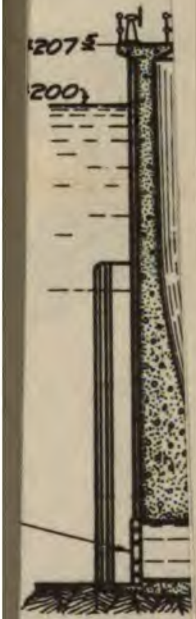
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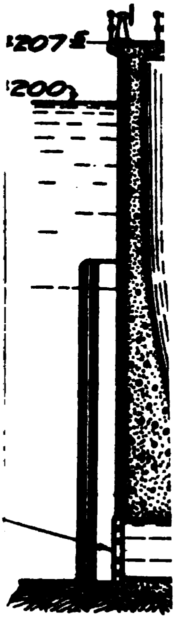
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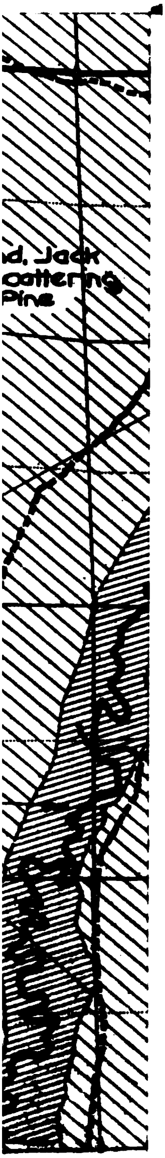
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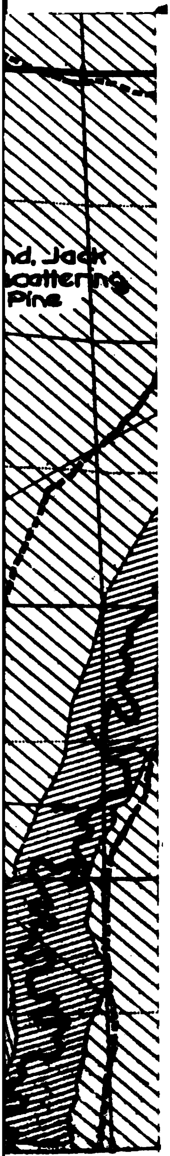
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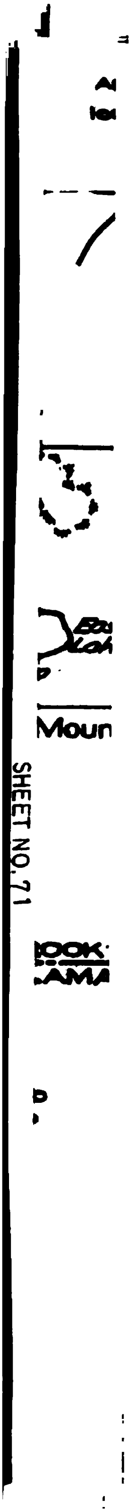

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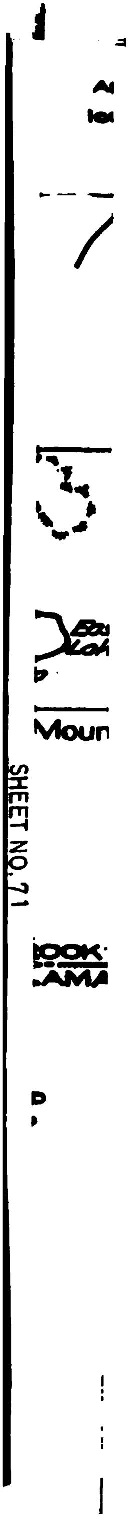

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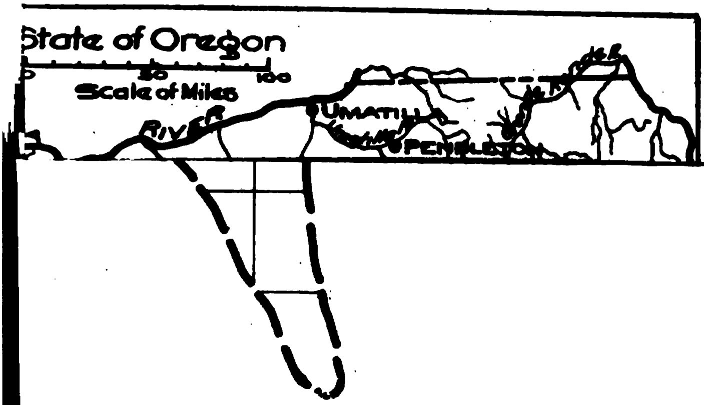
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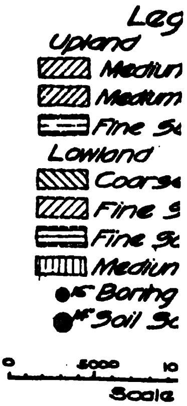
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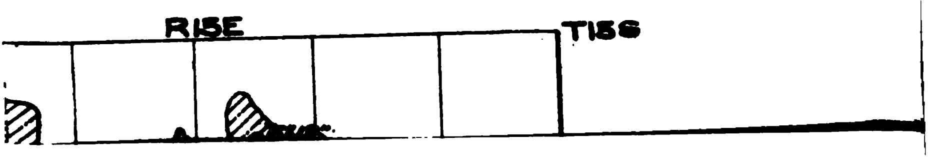

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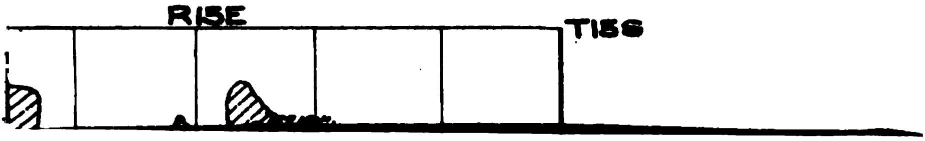

OREGON COOPERATIVE WORK

U. S. Reclamation Service and State of Oregon

Project Deschutes

Feature Soil Survey - South Unit

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